FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by H. M. STEVEN

VOLUME IV

Published by the
OXFORD UNIVERSITY PRESS
LONDON : HUMPHREY MILFORD
AMEN HOUSE, E.C. 4
1930

PRINTED IN GREAT BRITAIN

CONTENTS

Number 1

An Oak Seedling Disease caused by *Rosellinia quercina* Hartig. By J. S. L. WALDIE. (With Plate I) 1
Tracheid Length, with special reference to Sitka spruce (*Picea sitchensis* Carr.). By L. CHALK 7
Planting Tools and Methods. By JOHN MC EWEN 15
The Bearing of Some Ecological Conceptions on the Formation of Plantations. By H. M. STEVEN 26
The Seasoning of Timber. By S. T. C. STILLWELL 34
The Use of the Projection Apparatus in Anatomical Studies of Timbers. By S. H. CLARKE 40
Production of Hardwoods (Communicated by the Forestry Commissioners) 45

REVIEWS

Recent Research on the Microchemical Reactions of Woody Tissues. By B. J. RENDLE 50
Recent Research in the Hastening of the Germination of Tree Seeds. By H. M. STEVEN 52
The Economics of Forestry (W. E. HILEY). By PROFESSOR HENRY CLAY . 54
Loch Ossian Plantations (J. S. M.). By the EDITOR 55
Waldbau auf Ökologischer Grundlage (A. DENGLER). By the EDITOR . 56
Australian Rain-Forest Trees (W. D. FRANCIS). By W. DALLIMORE . . 57
Principles of Forest Entomology (S. A. GRAHAM). By J. W. MUNRO . 58
The Plant Rusts (J. C. ARTHUR and others). By W. R. DAY . . . 60
The Formation of Spring and Summer Wood in Ash and Douglas fir (L. CHALK). By S. H. CLARKE 61
Roadside Planting (R. B. A.). By the EDITOR 62

NOTICES

Handbook of Geology of Great Britain (edited by J. W. EVANS and C. J. STUBBLEFIELD) 63
A Map of England and Wales, showing the Distribution of Glacial Erratics and Drifts (F. W. HARMER) 63
Insects and Industry (J. W. MUNRO) 63
Empire Forestry Handbook (edited by FRASER STORY) 63
Webster's Foresters' Diary and Pocket Book, 1930 64

Number 2

Observations on *Armillaria mellea* in Pure Culture with certain Conifers. By M. C. RAYNER (With Plates II & III) 65
The Problem of Fire in British Forests. By W. L. TAYLOR . . . 78
The Differential Shrinkage of Wood. By S. H. CLARKE (With Plates IV & V) 93
Some Forest Pests in Bilberry Areas. By C. C. BROOKS (With Plate VI) 105
Some Experimental Studies on the Artificial Regeneration of Oak. By W. H. GUILLEBAUD 113
The Forestry Sub-section of the British Association for the Advancement of Science, 1930 122
European Beechwoods. By A. S. WATT 123
Conference on the Systematic Anatomy of Wood. By B. J. RENDLE . 128
The Society of American Foresters 130

REVIEWS

Review of Forestry Literature published in Finland in 1929. By U. METSÄNHEIMO 131
Recent Research in Plot Technique and Statistical Analysis. By H. M. STEVEN 133
Home Grown Timbers. Their Anatomical Structure and its Relation to Physical Properties. Elm (S. H. CLARKE). By L. CHALK . . . 135
Untersuchungen über den Einfluss der Fällzeit auf die Eigenschaften des Fichten- and Tannenholzes (H. KNUCHEL). By B. J. RENDLE . 137
Studies of the Sirex Parasites (R. N. CHRYSTAL). By W. R. THOMPSON . 138
Big Trees (WALTER FRY and JOHN R. WHITE). By the EDITOR . . 139
Tenth Annual Report of the Forestry Commissioners. By THOMAS THOMSON 139
Report of the Forest Products Research Board, 1929. By the EDITOR . 142
The Proceedings of the Third British Empire Forestry Conference, 1928. By THOMAS THOMSON. 143
Proceedings of the International Congress of Forestry Experimental Stations. Stockholm, 1929 144

SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed in 1925 and adopted its first Constitution at Oxford in 1926. The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The Society consists of Professional and Ordinary members. Professional membership is divided into two orders:

FELLOWS, being holders of a degree or diploma in forestry, and subjects of the British Crown, but not necessarily resident in Great Britain; and

ASSOCIATES, being subjects of the British Crown resident in Great Britain, whole-time foresters, and not eligible for Fellowship. They pay a less subscription than Fellows but have almost equal privileges.

Ordinary membership is open to persons not eligible for either of the above.

Office-bearers and Councillors are nominated by Professional Members, and in the event of competition for any office a postal ballot of the whole Professional Membership is held. The following were elected to serve in 1930:

President:	JOHN D. SUTHERLAND, C.B.E., LL.D., F.S.I., F.R.S.E.
Vice-President:	R. S. PEARSON, C.I.E., F.L.S.
Councillors:	R. L. ROBINSON, B.A., B.SC., O.B.F (immediate Past-President).
	JAMES LYFORD-PIKE, M.A., B.SC.
	FRANK SCOTT, O.B.E.
	THOMAS THOMSON, M.SC.
	LAURENCE CHALK, M.A., D.PHIL.
	SIR PETER CLUTTERBUCK, C.I.E., C.B.E.
	JAMES FRASER, B.SC.
Editor of Journal:	H. M. STEVEN, M.A., PH.D., 20 Alderman's Drive, Peterborough, Northants.
Business Editor:	L. A. NEWTON, B.A., 25 Drumsheugh Gardens, Edinburgh.
Editorial Committee:	THE EDITOR, THE BUSINESS EDITOR, DR. CHALK, MR. SCOTT, and MR. THOMSON.
Secretary and Treasurer:	R. ANGUS GALLOWAY, M.C., B.SC., Solicitor, 8 Rutland Square, Edinburgh.

THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is

gradually being built up. It is intended that this society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as ordinary members.

SUBSCRIPTIONS are:

Fellows and Ordinary members: £1 1*s*. 0*d*. annually or £10 10*s*. 0*d*. for Life.

Associates: 10*s*. 6*d*. annually.

THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year in May and November. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others, resident either in Great Britain or abroad. They should be sent to the editor, Dr. H. M. Steven, 20 Alderman's Drive, Peterborough, Northants. The papers should be typewritten, and on one side of the paper only. The paper should conclude with a summary of contents. It is understood that an article is not offered to any other journal for prior or simultaneous publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number enclosed in brackets. Twenty reprints of the article will be sent free to each contributor. Additional reprints may be purchased if ordered at the time when proofs are returned.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, R. Angus Galloway, 8 Rutland Square, Edinburgh.

SOCIETY'S MEDAL. The Council have resolved that the Society award a Medal from time to time to any individuals who may have rendered eminent services.

AN OAK SEEDLING DISEASE CAUSED BY *ROSELLINIA QUERCINA* HARTIG

BY JOHN S. L. WALDIE

University of Reading

GENERAL STATUS OF THE FUNGUS.

ROSELLINIA QUERCINA occurs as a parasite of young oak seedlings, affecting the roots and the lower parts of the stem, and is particularly serious when it is present in the seed-beds. The effects of the fungus are manifest by an unhealthy colour of the leaves, followed by withering and wilting, while around the roots and often on the lower portion of the stem will be found a felt-like mycelium of interwoven brownish hyphae.

The disease has been known to exist for more than eighty years in Germany, where it was first recognized. Hartig (2) in 1880 gave a full account of the symptoms of the disease and the causal fungus, but the disease was known to exist in Germany as early as 1850. After 1850 the disease appeared sporadically in 1860, 1865, and 1875 in several forest areas, and in 1875 Hartig gave the name *Rhizoctonia quercina* to the fungus, as it was not until 1880 that he found the fruiting stage of the fungus, when he assigned it to the genus *Rosellinia* as *R. quercina*. Rostrup (3) recorded its presence in Denmark in 1882 on oaks produced from acorns of German origin. Delacroix and Maublanc (1) state that the fungus is rare in France.

OCCURRENCE IN GREAT BRITAIN.

Rosellinia quercina has up to the present been relatively rare in Britain. The only previous note of its occurrence in this country is by Wheldon (5), who recorded it on oak seedlings in Lancashire in 1909.

In June 1927 oak seedlings were seen by the writer to be dying off in patches in the seed-beds at Kennington Nursery, near Oxford. The seedlings were kept under observation throughout that summer, and in the autumn the causal fungus was identified as *Rosellinia quercina*. An outbreak of the disease was again seen in June 1928 in the same nursery, but was not of a serious nature, while in June 1929 isolated plants were also attacked. By removal of the diseased plants in the early stage of the attack in these latter outbreaks the progress of the disease was checked. Mr. W. R. Day, Imperial Forestry Institute, noted an attack of *Rosellinia quercina* on direct-sown oak seedlings in 1929 near Nagshead, Forest of Dean.

SYMPTOMS OF ATTACK.

The first signs of the disease were seen on the 15th June, 1927, when the topmost leaves of the seedlings became blue-green in colour, turning yellow gradually in the course of a few days, while the lower leaves retained their normal bright green, healthy appearance. About a week later the latter also

changed their colour, and within a short time the whole plant had a brown, withered appearance. The disease usually began in a small area in the seed-beds, and gradually spread from this centre of infection. From the beginning of July the fungus spread fairly rapidly, but towards the middle of that month the virulence of the disease tended to diminish, though it continued to spread to all the seed-beds in August and September. The rapid increase of the disease during June and the earlier part of July of 1927 might be due to the wet weather, because almost twice the normal rainfall was experienced during this period, combined with rather cold spells. It is interesting to note that Hartig found in Germany that the fungus did much more damage in cold wet years, and the outstanding features of the weather during the summer months and early autumn of 1927 were the persistent rain and lack of sunshine. On pulling up the diseased seedlings, the tap-roots were found to be partially, and in some cases almost completely, destroyed. Others had developed a new root system from the upper part of the root with more or less success, while at a depth of two to three inches below the surface of the soil, the main root ended in a rotten stump. Between the bark and the wood of these diseased roots a white mycelium was present, accompanied by a felt of violet-brown hyphae on the outside of the upper part of the root, which still remained alive. From the appearance of this felt-like mycelium, and the manner in which it formed strands, there was every suggestion of *Rhizoctonia*, but on microscopic examination the characteristic clamp connexions on the hyphae of *Rhizoctonia* were absent, which showed that the disease was due to some other fungus. Hartig also observed this external similarity of the mycelium of *Rosellinia* to *Rhizoctonia*, and in 1875 in the absence of the perfect stage of the fungus provisionally gave the fungus the name of *Rhizoctonia quercina*.

On microscopic examination, the hyphae are found to be colourless in their early stages, that is to say, near their growing points, but change to a brown colour as they get older. The mycelial strands are formed by the association of the hyphae. The felt of mycelium is most abundant on the collar of the oak seedling just at the soil level, but also extends down the root and up the stem for half an inch or more.

It is usually found in an outbreak of the disease in a seed-bed that apparently healthy plants in the vicinity of wilted plants are likely to be infected. This can be confirmed by pulling up the seedlings and examining the roots for the presence of the mycelium. A careful inspection of soil adhering to the roots will show many ramifying fungal threads. The spread of infection in summer occurs principally from the mycelium in the soil, as the disease spreads out radially in all directions from the centre of infection when the acorns have been sown broadcast; while if they have been sown in drills the disease works along the lines.

During July and August the fungus continues to spread in this fashion and on close examination the hyphal strands and individual hyphae can be seen passing from one seedling to another. This was particularly so in the season of 1927 when the soil was exceedingly wet, again showing that *Rosellinia*

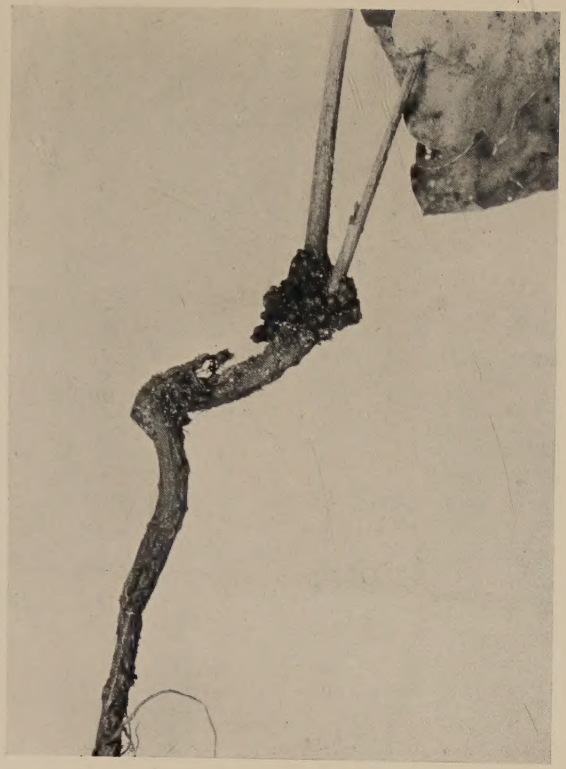


FIG. 1. Oak seedling with young perithecia on the lower part of the stem. Natural size.

FIG. 2. Perithecia on stem of oak seedling. × about 2·5.

prefers rather moist conditions. In 1928 and 1929 when there was continued drought with drying out of the soil, the fungus did not make rapid progress, which indicates that it is sensitive to dry conditions. This fact, combined with the control measures adopted in 1927, may partly account for the much lower death-rate among the oak seedlings in 1928 and 1929 due to *Rosellinia quercina*.

DESCRIPTION OF THE FUNGUS.

The mycelium of *Rosellinia quercina* consists in its early stages of colourless septate hyphae, 4μ to 7μ in diameter, later becoming branched in all directions, and where they cross one another they grow together by fusions, while others growing laterally fuse to form thick strands. The hyphae ramify in all directions until an irregular web is formed, and they turn gradually brown in colour—usually after fourteen days.

If a microscopic examination is made of the mycelium round the collar of the oak seedling during the summer and the hyphae growing over the surface of the soil, small upright conidiophores are found. The hyphae which function as conidiophores possess lateral branches in whorls of threes or fives, and from these branches simple short conidia are budded off. The part played by the conidia in the life history of the fungus is not known.

As the season advanced and about the middle of September the perithecia of the fungus began to form in the thick-felted mycelium on the stem (Fig. 1), immediately above the soil level. These were fully developed in about a month. In addition, perithecia were found on the surface of the soil surrounding the diseased plants. On close examination of the perithecial stage, there was no doubt that the disease was due to *Rosellinia quercina*. The genus *Rosellinia* belongs to the family Sphaeriaceae of the Pyrenomycetes, a subdivision of the Ascomycetes, characterized by the possession of a closed perithecium. Briefly the perithecia are small, black, globose bodies either free or partly embedded in the substratum of hyphae. The perithecia were formed abundantly, though in Germany they are not produced freely.

The formation of perithecia was not closely observed, though the following points were noted. The perithecia are at first embedded in the mycelium which changes in its character of growth, through the hyphae growing together into a crust or cushion-like structure, and from these cushions the developing perithecia gradually grow out. Owing to the presence of this cushion-like body, the early stages in the development of the perithecia are concealed, and the first sign of the perithecial formation is the appearance of their small ostioles or mouths. When the perithecia emerge from the substratum they are at first a dull grey-brown in colour, but gradually get darker. The mature perithecium is black, has a hard carbonaceous wall with the small papilla-like projection or ostiole at its apex, and when ripe is almost completely superficial (Fig. 2). The perithecia are from 0·8 to 1 mm. in diameter. The inside wall, except around the ostiole, is covered by a layer consisting of asci and paraphyses. The paraphyses are septate, cylindrical, and about 210μ by 3μ in size.

The asci are at first cylindrical, when their contents have a granular appearance, gradually increase in diameter, and are 180μ by 10μ in size when mature. The apex of the ascus thickens to such an extent that the lumen becomes a very narrow channel. The thickened apex takes up water readily, and on swelling the lumen cannot be observed. When stained with iodine solution the thickened portion becomes bright blue in colour—a characteristic reaction in species of *Rosellinia*. The ascus contains eight ascospores, which in their early stages are often joined together by their pointed ends. The spores are as a rule arranged in a single row in the ascus and when ripe are brown in colour. The ascospores are about 30μ by 8μ in size, spindle-shaped, slightly bent, and contain several oil drops. On the flatter and shorter side of the spore, there can be seen a fine line which extends for three-quarters of the way along the spore. The ascospores are fully formed by the end of October, but do not escape from the perithecium until the following spring.

METHOD OF INFECTION.

Rosellinia quercina may be spread in the spring by germinating ascospores or by a resting mycelium, which may be in the form of small sclerotia. Either of these stages may have overwintered in the soil; or, on the other hand, plants slightly infected, though not yet killed, may spread the disease when conditions become suitable for fungal growth. The spread of the parasite throughout the summer is at any rate by means of the mycelium spreading over the surface or in the soil from one plant to another. During the summer the fungus can spread over an area of approximately one square yard. The second method of propagation in the summer may be possible by the dispersal of conidia by wind and rain. If so, this may partly account for the disease being more severe in a wet year by the washing of conidia through the seed-bed.

Infection by *Rosellinia* hyphae of an oak seedling is through young lateral roots unprotected by periderm and then through the wounds left by the death of these lateral roots. The mycelium penetrates from these wounds into the cortex of the root, then works its way into the wood and medulla, with the result that in a heavy infection the root is hollowed out and only the bark remains. Hartig has shown that when a lateral root is killed by the hyphae an open wound is left in the bark, due to the absence of a cork layer, and through which the parasite gains an entrance in rather a strange manner. At such points above and below the base of the dead rootlet, mycelial outgrowths are formed, which later become dark in colour, resemble sclerotia, and send out mycelial processes into the root-tissues. If conditions unfavourable to the parasite arise, the host-tissue has time to form a cork barrier around these dead root points, so that the fungus is unable to penetrate the oak root and further damage to the seedling is avoided. Infection rarely occurs at a point where there is no lateral root, though it is probable that small wounds in the root may give entrance to the fungus.

AGE AND SPECIES OF TREE ATTACKED.

Rosellinia quercina is generally looked upon as a seedling disease and this

appeared to be the case at Kennington, as oak seedlings only were observed to suffer. In Germany the disease is rare on plants above three years old. Seedlings of the sessile oak (*Quercus robur sessiliflora*), the pedunculate oak (*Q. robur pedunculata*), and the Turkey oak (*Q. Cerris*) were all attacked by the fungus. Oak transplants, even when grown in close proximity to heavily infected seedlings, remained free from the disease. The same was found to be the case when seedlings of other deciduous trees were grown beside diseased oaks. In Denmark, however, *Rosellinia quercina* has been recorded by Rostrup (3) on the beech (*Fagus sylvatica*) and sycamore (*Acer pseudoplatanus*). There is no record of the occurrence of this species on young conifers, although it is interesting to note that Wilson (6) has described the attack of the closely related species *Rosellinia aquila* on two-year-old plants of common spruce (*Picea excelsa*) in a nursery in the south of Scotland. Attempts were made by the writer to infect coniferous seedlings with *R. quercina* by growing them in contact with diseased oak seedlings, but without success.

SOURCE OF THE DISEASE.

It is exceedingly difficult to account for the presence of the fungus in Kennington Nursery, because the ground in the infected area had not carried oaks before, and the nursery was broken up from pasture land only two years previous to the outbreak. There is the possibility that it may have been introduced with acorns. At the beginning of the outbreak the disease was restricted to small patches in the seed-beds, and in some cases it appeared to be spreading from dead acorns. The disease appeared simultaneously in a number of plots where acorns from different localities had been sown. These acorns came from a wide range of localities in England from north to south. In Denmark (3) the disease was first discovered on oaks produced from acorns from Germany, while oaks of Danish origin close by were not attacked. It is very unlikely that the fungus was present in the soil previously, unless it was parasite on some other host plant, for example some leguminous crop. To throw some light on this possibility, infection experiments were carried out with the mycelium of *Rosellinia* on wild white clover plants. These trials, however, gave negative results.

MORTALITY AND CONTROL MEASURES.

In the 1927 outbreak at Oxford the mortality of oak seedlings varied from 20 per cent. in some seed-beds to 100 per cent. in others. The seriousness of the disease was recognized early, so that strong measures of control were adopted. All diseased seedlings were carefully removed from the soil and burnt, care being taken at the same time to grub up the roots as carefully as possible. An attempt was also made to check the progress of the fungus in the soil by applying a 2 per cent. solution of carbolic acid, as recommended by Salmon (4), against the mycelium of *Rhizoctonia violacea* in the soil, but the disease still tended to spread. Stronger measures were then adopted; the soil in the infected area was burnt over by a powerful primus blow-lamp, the soil being constantly turned so that it was treated to a depth of 6 inches or more.

After this a 5 per cent. solution of carbolic acid was applied to the soil at the rate of 2 gallons per square yard. This method proved very successful in checking the disease and apparently had no ill effects on the soil, because coniferous transplants which were placed in the ground in the following year made excellent growth.

REFERENCES

(1) Delacroix et Maublanc: *Maladies parasitaires des Plantes Cultivées*, p. 230, 1926.
(2) Hartig, R.: *Untersuchungen aus d. Forstbot. Institut. zu München*, i, p. 1, 1880.
(3) Lind, J.: *Danish Fungi as represented in the Herbarium of E. Rostrup*, p. 192, 1913.
(4) Salmon, E. S.: 'Diseases of Seakale.' *Gardener's Chronicle*, vol. xliv, 3rd Series, p. 1, July 1908.
(5) Wheldon, H. J.: 'Lancashire Ascomycetes.' *Journal of Botany*, vol. 50, p. 185, 1912.
(6) Wilson, M.: 'Studies in the Pathology of Young Trees and Seedlings.' *Trans. Roy. Scot. Arbor. Soc.*, vol. 36, p. 226, 1922.

TRACHEID LENGTH, WITH SPECIAL REFERENCE TO SITKA SPRUCE (*PICEA SITCHENSIS* CARR.)

BY L. CHALK

Imperial Forestry Institute, Oxford

INTRODUCTION.

THERE appears to be little or no connexion between the length of the fibres or tracheids in a timber and its mechanical properties. The study of variation in length, apart from its relation to the pulp industry, may therefore seem to be of academic interest only. This is probably true, in so far as it has no immediate practical application, but the work which has been done on this subject has brought to light definite trends of variation within the individual tree which are of very great interest in their bearing on the general problem of changes in cell dimensions. One important aspect of this problem lies in its relation to the selection of samples for anatomical study. While practically the whole of the tree may be examined for purposes of mechanical tests, microscopic examination of the anatomy of the wood can, in practice, only be carried out on a limited number of samples, and it is obvious, therefore, that a knowledge of the probable variation within a tree is essential if material from different trees is to be compared.

MATERIAL.

The following investigation was limited to a single tree of Sitka spruce.

The tree was from a plantation at Durris, Kincardineshire, and was supplied by the courtesy of the Forestry Commission. The exact age of the plantation is not known, but it probably dates from about 1882, and is reputed to be one of the oldest plantations of Sitka spruce in Europe.

The stand is at an elevation of 800 feet, with a north aspect, and is moderately exposed, while the soil consists of peat on boulder clay over Felspathic Gneiss. The tree investigated was felled in 1925, and was 71 feet high and 35 inches in girth at breast height.

METHODS.

Cross-section disks were cut at 3 feet above the ground and at approximately 13-feet intervals up the tree. The north, east, south, and west radii were marked on each disk and samples were cut from along these radii, to include the rings formed in 1900, 1910, and 1920. These samples, which were subsequently trimmed so as to include one ring only, were divided into spring and summer wood. They were then macerated by the potassium chlorate and nitric acid method, and the lengths of the tracheids were measured under a microscope. One hundred measurements were made from each sample and the corresponding figures for each radius grouped together. Each of the figures given in the

table, therefore, represents the average of 400 measurements. In order to obtain some guide as to the number of measurements necessary to obtain a reasonably accurate average, the measurements were plotted in a frequency curve. This brought to light an interesting point, namely, the importance of using a tangential rather than a radial chip for maceration, if no elaborate method of mixing the tracheids is used. At the outset a radial chip was used, on the grounds that, if there is a gradual change in length from the inside to the outside of the ring, it would be important to include tracheids equally from all parts of the ring.

Fifty measurements gave a very irregular frequency curve, which was only slightly improved by increasing the number to one hundred. It seemed probable that the selection of the material was at fault. The use of thin radial chips for maceration ensured measuring tracheids from all parts of the ring, but there is a likelihood of the daughter cells of one or two cambial initials predominating. It seemed advisable therefore to find out whether the differences through the ring in a radial direction were likely to be greater or less than the differences between adjacent rows.

An attempt was made to dissect out a single radial row of tracheids. This was never actually achieved, but in a few cases dissection was carried to the point of leaving a pair of rows about 20 cells long. The two rows were easily distinguished by focusing, and measurements were made of the lengths of the tracheids in each. It was found that fluctuations in the length along a single row of tracheids were very slight in comparison with the differences between adjacent rows. For example, in one row of 20 cells, the length varied between 3·40 and 3·69 mm., while in the next row the range was from 2·05 to 2·16 mm. It seemed more important therefore to include cells from as many cambial initials as possible, rather than to aim at an even distribution of cells from all parts of the radius. This object was attained by using tangential instead of radial chips, and the measurements gave much more satisfactory frequency curves. Fifty measurements still proved hardly sufficient and 100 was accordingly adopted as a minimum number for each sample.

EXPERIMENTAL RESULTS.

The average lengths of the tracheids measured at different points in the stem are given in the following table.

TABLE I. *Tracheid length, in mm.*

	1916–25			1906–15			1896–1905		
Ht. above ground.	*Spring wood.*	*Summer wood.*	*Av.*	*Spring wood.*	*Summer wood.*	*Av.*	*Spring wood.*	*Summer wood.*	*Av.*
3 ft.	2·635	2·810	2·721	2·370	2·632	2.495	2·018	2·312	2·160
16 ft.	3·015	3·275	3·145	2·405	2·855	2·630	1·782	2·138	1·960
29 ft.	2·760	2·970	2·870	1·982	2·180	2·082			
41 ft.	2·385	2·835	2·610						

Spring and summer wood. The average tracheid length of the summer wood was distinctly greater than that of the spring wood in each case, the difference amounting to about 12 per cent.

Variation outwards from the pith. In each disk the average length was least near the pith and increased regularly outwards towards the bark. This increase

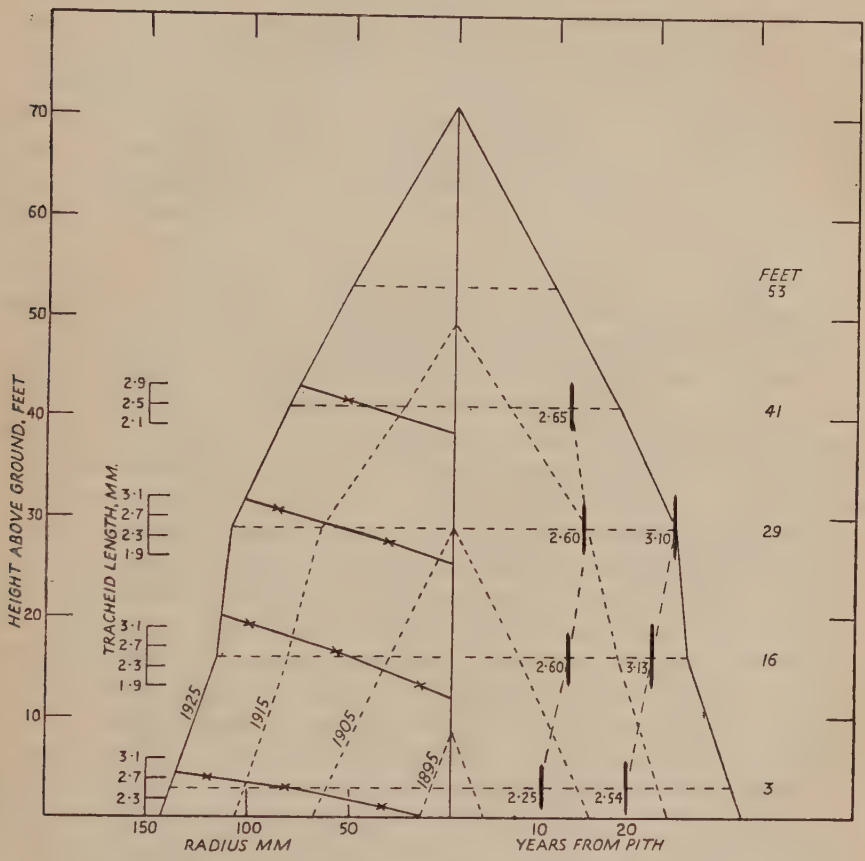


FIG. 1.

in length outwards was least marked in the lowest disk (3 feet above ground). These points are illustrated on the left-hand side of Figure 1.

Variation upwards. Tracing the same ring upwards in the tree, it was found that, in the 1910 and 1920 rings, length increased from the base upwards, was greatest at 16 feet, and above this decreased towards the top of the tree. In the innermost ring measured (1900), the greatest length occurred at 3 feet above the ground.

The selection of samples was not designed to show the effect of height on rings the same age from the pith, but figures for rings 10 and 20 years from the pith at different heights were obtained indirectly, by interpolation in the curves

shown on the left-hand side of Figure 1. The lengths thus obtained are shown on the right-hand side.

These figures show that length, at both 10 and 20 years from the pith, increases from the base to a height of 16 feet and above that remains approximately constant.

Relation to ring width. It was found that the longest tracheids on each cross-section were usually from the narrowest part of the ring. For example in the 1920 ring, at 16 feet, on the north radius the ring width was 4·4 mm., and length 3·11 mm., while on the west radius the width was 3·0 mm. and length 3·41 mm. Similarly in the 1910 ring on the same radii the widths were 5·2 and 4·7 mm. and the lengths 2·62 and 2·87 mm. Using all the measurements throughout the tree a correlation coefficient was calculated for ring width and tracheid length. The value of this coefficient was $-0{\cdot}742 \pm 0{\cdot}055$.

DISCUSSION.

Spring and summer wood. The greater length of the summer wood tracheids of the Sitka spruce is in accordance with the observations of Lee and Smith (6) on Douglas fir, and of Kribs (5) on Jack pine. Gerry (3), on the other hand, found that, in long-leaf pine and Douglas fir, the spring wood tracheids were longer than those of the summer wood, and it is stated in Madison *Technical Notes* (12) that the longest tracheids are generally those formed in the early spring wood, and the shortest are those in the last-formed summer wood.

Variation outwards from the pith. An increase in length outwards from the pith, such as was found in the Sitka spruce, has been observed near the centre of the tree by all investigators, and may be assumed to be of general occurrence. This increase is not, however, continued indefinitely outwards to the bark in the old trees, but ceases after a number of years and the length outside this remains approximately constant. The length of this period of rapid increase varies considerably in different species and probably in different trees of the same species. For example, Prichard and Bailey (9) found the length of this period in *Carya ovata* K. Koch. to be 20–25 years, Lee and Smith (6), in *Pseudotsuga taxifolia* Brit., about 50 years, and Harlow (4), in *Thuya occidentalis* L., up to 100 years. Bailey (1) has affirmed that the size of the tracheids is largely dependent on the length of the cambial initials, and has stated that the length of these increases for 100 years in the conifers, and then remains constant. In the Sitka spruce all the wood examined appears to lie within this period of increasing length.

It has been suggested that this period corresponds to the period of maximum height growth. MacMillan (7) and Lee and Smith (6) observed that, although such a relationship seemed to occur in the early life of the tree, there was no change in tracheid length when the rate of height growth fell off at a more advanced age.

Considerable prominence was at one time given to the question of whether or not the tree settled down to a constant tracheid length after this preliminary period. Sanio's (10) figures for Scots pine showed so little variation in

the outer part of the tree, that it was hoped that tracheid length would prove of great value for purposes of identification. Bailey and Shepard (2) investigated four coniferous species in 1914 and found that there were considerable fluctuations after the initial period of increase. This has been found to be the case in several other species since investigated, and the use of tracheid length as a means of identification has fallen into disrepute.

Both Kribs (5) and Bailey and Shepard (2) noted a temporary decrease in length for 10 years after the initial period of increase was over.

It has been affirmed that, in very old trees, length decreases gradually towards the outside. Bailey and Shepard (2) found that in the long-leaf pine length rose to a maximum at 160 years and then decreased. Lee and Smith (6) also noticed that length tended to decrease slightly towards the periphery in Douglas fir, particularly at the base. On the other hand, Gerry (3) examined a 455-year-old Douglas fir to elucidate this point, and found that old age had no effect on the size of the elements.

It has already been stated that, in the Sitka spruce, the increase in length from the pith outwards was more gradual in the lowest section than at higher levels in the tree. Kribs (5) and Lee and Smith (6) have also observed a less rapid increase outwards in the lower parts of the tree. This point appears to have considerable significance in relation to the types of variation which have been observed up and down the tree and will be referred to in the following section.

Variation upwards. The first point to receive attention, in connexion with variation in length at different heights in the stem, was the change in a single ring traced upwards through successive sections. It has been found that, in any ring, length increases from the base upwards to a maximum, and then decreases towards the top of the tree. In the Sitka spruce the maximum length measured was at 3 feet in the 1900 ring and at 16 feet in the 1910 and 1920 rings. The greater height at which the maximum occurs in the outer, as compared with the 1900, ring, confirms the results of Bailey and Shepard (2) and Lee and Smith (6), who found that the height at which the maximum length occurs increases with the distance from the pith.

Kribs (5) investigated the effect of height in the tree from rather a different standpoint. Instead of tracing the same ring upwards, he arranged his measurements so as to group together all rings of the same age from the pith. He thus showed what appears, at first sight, to be yet a third type of variation, namely, a rapid increase in tracheid length from the base upwards for a short distance, after which there is a slight decrease towards the top of the tree. The three types of variation which have been observed are therefore: (1) outwards at the same level, (2) upwards in the same ring, and (3) upwards at the same number of rings from the pith. It should be borne in mind, however, that these three types may be merely the same phenomenon measured in three different ways.

For example, it is obvious that as one traces any single year's growth upwards the number of rings separating it from the pith decreases. Variation of

the first type therefore must be considered as playing some part in the change upwards and may conceivably be the sole cause of it.

If the rate of increase outwards from the pith were the same at all levels in the tree, one would expect that, at any definite age (number of rings) from the pith, the tracheids would be of a constant length irrespective of their height in the tree. Actually there are differences between different heights in the stem in regard to the rate of increase outwards from the pith, and it is of interest to see whether these differences are reflected in the length at any given age from the pith. This can perhaps be most easily discussed in relation to the diagram on p. 9.

The rate of increase outwards at different levels is represented by the steepness of the curves on the left-hand side of the figure. It will be noticed that at 3 feet the rate of increase is much slower than at the higher levels in the tree. It may, therefore, be assumed that in ten years the tracheids will have increased to a greater length at 16 feet than at 3 feet.

It will be seen that this is so, by looking at the right-hand side of the diagram, where the length is given at 10 years from the pith at different heights. It will also be seen that at 29 feet, where the rate of increase is nearly the same as at 16 feet, the length at 10 years from the pith remains unchanged. At 20 years from the pith, length varies in precisely the same manner.

This sharp increase in length above the base has been very clearly demonstrated by Kribs (5), except in the ring next to the pith, and was referred to above in the third type. It is also shown diagrammatically by Lee and Smith (6). Kribs's curves appear to show also that the height in the tree, at which this maximum occurs, increases with age from the pith. This appears to be a necessary corollary of the point made by Bailey and Shepard (2), and Lee and Smith (6), who, in tracing the same ring upwards, observed that the maximum length occurs higher in the tree in the outer than in the inner rings. According to Kribs (5), the curves showing the increase outwards from the pith are more nearly linear towards the top of the tree than at the base, and there is consequently a higher correlation coefficient between age from the pith and length of tracheid in the upper sections of the tree.

There seems little doubt, therefore, that the relatively slow rate of increase outwards from the pith at the base (compared with the rate at higher levels in the tree) is essentially the same phenomenon as the sharp rise in length above the base, which has been observed in tracing upwards a series of rings, each of which is the same age from the pith.

So far, only the marked differences which occur at the base of the tree have been discussed. These, owing to their magnitude, are the most striking feature of variation upwards. What happens after this rise at the base, in rings of the same age from the pith, is not quite so clear. In the Sitka spruce length remained approximately constant in the upper part of the tree, but the number of samples was hardly sufficient to demonstrate this completely. From the diagram given by Lee and Smith (6) for a Douglas fir tree, it would also appear that, at the same distance from the pith, length remained approximately con-

stant in the upper parts of the tree. Kribs (5), however, found a slight decrease in length towards the top of the tree. This decrease was very slight compared with the variation due to distance from the pith, and one seems justified in assuming that length at the same age from the pith remains approximately constant in the upper parts of the tree. In that case, it would appear that the gradual decrease towards the top of the tree which has been observed in tracing the same ring upwards may also be due to the relation between age from the pith and length.

It seems probable therefore that the changes which have been observed at different heights in the stem are largely due to the effect of the height on the rate of increase outwards from the pith, and that a study of the factors influencing this rate offers a hopeful field for research into the cause of variation.

Relation to ring width. The negative correlation between width of ring and tracheid length was more definite than was expected. Gerry (3) and Lee and Smith (6) have indicated that a broad ring may be correlated with a shorter tracheid, but Sanio (10) and Shepard and Bailey (11) failed to find any relation between tracheid length and width of ring.

Observations on different trees growing at different rates appear to show the reverse of this relationship. MacMillan (7) found that, in *Picea rubens* Sarg., the tracheids from suppressed trees were about 10 per cent. shorter than in freer growing trees, and Mell (8) that, in *Juglans californica* Wats., the fibres were longer in fast-growing trees from rich soils than in slow-growing trees from poor soils. Harlow (4) failed to find any appreciable difference in tracheid length, in *Thuya occidentalis* L., between trees grown on limestone and on peat bog, though growth was distinctly more vigorous on the limestone.

SUMMARY.

The following conclusions were reached from a study of the tracheids in a Sitka spruce tree, approximately 40 years old.

1. On each cross-section there was an increase in tracheid length from the pith outwards; this increase was least marked in the lowest section.

2. In the same ring traced upwards, tracheid length increased from the base upwards, reached a maximum, and then decreased towards the top of the tree.

3. At the same number of rings from the pith, tracheid length was lowest at 3 feet, increased rapidly upwards to 16 feet, and remained approximately constant in the upper parts of the tree.

4. The variation upwards in the tree appeared to be largely due to the differences in the rate of increase outwards from the pith at different heights in the stem.

5. The summer wood tracheids were about 12 per cent. longer than those of the spring wood.

6. On any cross-section the longest tracheids in any one ring were usually from the narrowest part and the shortest from the broadest part of the ring. A correlation coefficient of $-0{\cdot}742 \pm 0{\cdot}055$, for all the samples measured, was obtained between tracheid length and width of ring.

REFERENCES

(1) Bailey, I. W.: 'Size of variations of cambial initials in gymnosperms and angiosperms.' *Am. Journ. Bot.*, vol. 7, pp. 355–67, 1920.

(2) Bailey, I. W., and Shepard, H. B.: 'Sanio's laws for the variation in size of coniferous tracheids.' *Bot. Gaz.*, vol. 60, pp. 66–71, 1915.

(3) Gerry, E.: 'A comparison of tracheid dimensions in Longleaf pine and Douglas fir, with data on the strength and length, mean diameter and thickness of wall of the tracheids.' *Science*, vol. 43, p. 360, 1916.

(4) Harlow, W. M.: 'The effect of the site on the structure and growth of white cedar, *Thuya occidentalis* L.' *Ecology*, vol. 8, no. 4, pp. 453–70, 1927.

(5) Kribs, D. A.: 'Length of tracheids in Jack Pine in relation to their position in the vertical and horizontal axes of the tree.' *Univ. of Minnesota Agric. Exp. Station Techn. Bull.*, no. 54, pp. 14, 1928.

(6) Lee, H. N., and Smith, E. M.: 'Douglas fir fibres, with special reference to length.' *For. Quart.*, vol. 14, pp. 671–95, 1916.

(7) MacMillan, W. B.: 'A study in comparative lengths of tracheids of red spruce grown under free and suppressed conditions.' *Journal of Forestry*, vol. 23, pp. 34–42, 1925.

(8) Mell, C. D.: 'Determination of quality of locality by fibre length of wood.' *For. Quart.*, vol. 8, pp. 419–22, 1910.

(9) Prichard, R. P., and Bailey, I. W.: 'The significance of certain variations in the anatomical structure of wood.' *For. Quart.*, vol. 14, pp. 662–70, 1916.

(10) Sanio, K.: 'Uber die Grösse der Holzzellen bei der gemeinen Kiefer (*Pinus silvestris*).' *Jahrb. f. wissenschaftl. Bot.*, vol. 8, pp. 401–20, 1872.

(11) Shepard, H. B., and Bailey, I. W.: 'Some observations on the variation in length of coniferous fibres.' *Proc. Soc. Am. For.*, vol. 9, pp. 522–7, 1914.

(12) *Technical Notes.* Forest Products Laboratory, Madison, no. 95, 1920.

PLANTING TOOLS AND METHODS

BY JOHN McEWEN

Inspector of Forests, Dublin

NICOL, in the Introduction to his *Practical Planter* (1799), writes: 'I conceive it the duty of every one who has got a mite to offer, of useful information, to do so chearfully, and without restraint.' Those of us who have been field men may have a few mites and would offer these 'chearfully', but we have the 'restraint' of doing so in company with expert penmen. Further, the actual work in the forest is so familiar to us and seems so commonplace that we do not consider such of any great value, and also there is great difficulty in writing understandable descriptions of the details of field operations.

Forestry always has been, and will probably continue to be, the work of the handicraftsman, especially in the 'formation' stages of the crop, and to-day the hand tools in use are in the main similar to, and built on the same lines as, those used over a hundred years ago. The result is that to-day we have about half a dozen different types of planting spade for general planting purposes, and it is doubtful if much or any improvement can be made in these tools. There has been one important break-away from 'type' in the more or less modern semicircular spade designed by the late Mr. Murray when Head Forester at Murthy Castle. This spade is now fairly well known, but its outstanding qualities as a planting tool have not yet been fully realized by the foresters of this country. In addition to the spades there are tools of the pick type used for planting, the planting mattock being the most common one.

DESCRIPTION OF PLANTING TOOLS.

A short descriptive note on each of the planting tools most generally used may be found helpful.

(1) *Ordinary* (*Scotch pattern*) *digging spade.* In Scotland, at least, this is the pattern of spade most generally in use for planting. It is made in several sizes, but the no. 2 is best. The blade is of cast steel, $11\frac{1}{2}$ inches long by $7\frac{1}{2}$ inches wide, the sides being parallel; at the top this blade should not exceed $\frac{1}{8}$ inch in thickness and taper to just under $\frac{1}{16}$ inch at the bottom. The handle is of the box pattern, 28 inches long, with double scales 12 inches long, and three rivets. It is of the 'swan-neck' type, but with only a medium amount of 'lift'. The top of the blade is fitted with treads. The above dimensions give a very fleet strong tool not exceeding $2\frac{1}{2}$ lb. in weight.

(2) *Irish pattern spade.* This spade is similar to the above, except that the blade is 13 inches long, tapering from 7 inches wide at the top to 6 inches at the bottom, with thickness of blade the same as in the Scotch pattern. The handle also is similar, with a 'lift', but is 2 inches longer.

(3) *Schlich.* This is a straight-handled spade, with handle 28 inches long, and double straps the full length of the handle. The blade is 10 inches long

and 6 inches wide, with sides parallel for about two-thirds of the length and then coming sharply to a point. The blade is thin at the point and on the sides, but bulges somewhat in the centre, and its weight should be not less than 3 lb. It is a very strong spade.

(4) *Mansfield or Learney.* A straight-handled spade with handle exactly similar to the 'Schlich'. The blade, however, is longer, being 12 to 13 inches and tapering in width from 6 inches at the top to 4 inches at the bottom, and in thickness it is similar to the Irish pattern. Weight should be just under 3 lb.

(5) *Circled digging spade.* This is a straight, box-handled spade with 12-inch scales. There are several sizes of blade, the average being 12 inches long by $5\frac{1}{2}$ inches wide. The sides are parallel and there is a 'dish' of $\frac{7}{8}$ inch on the blade. It is a strong tool.

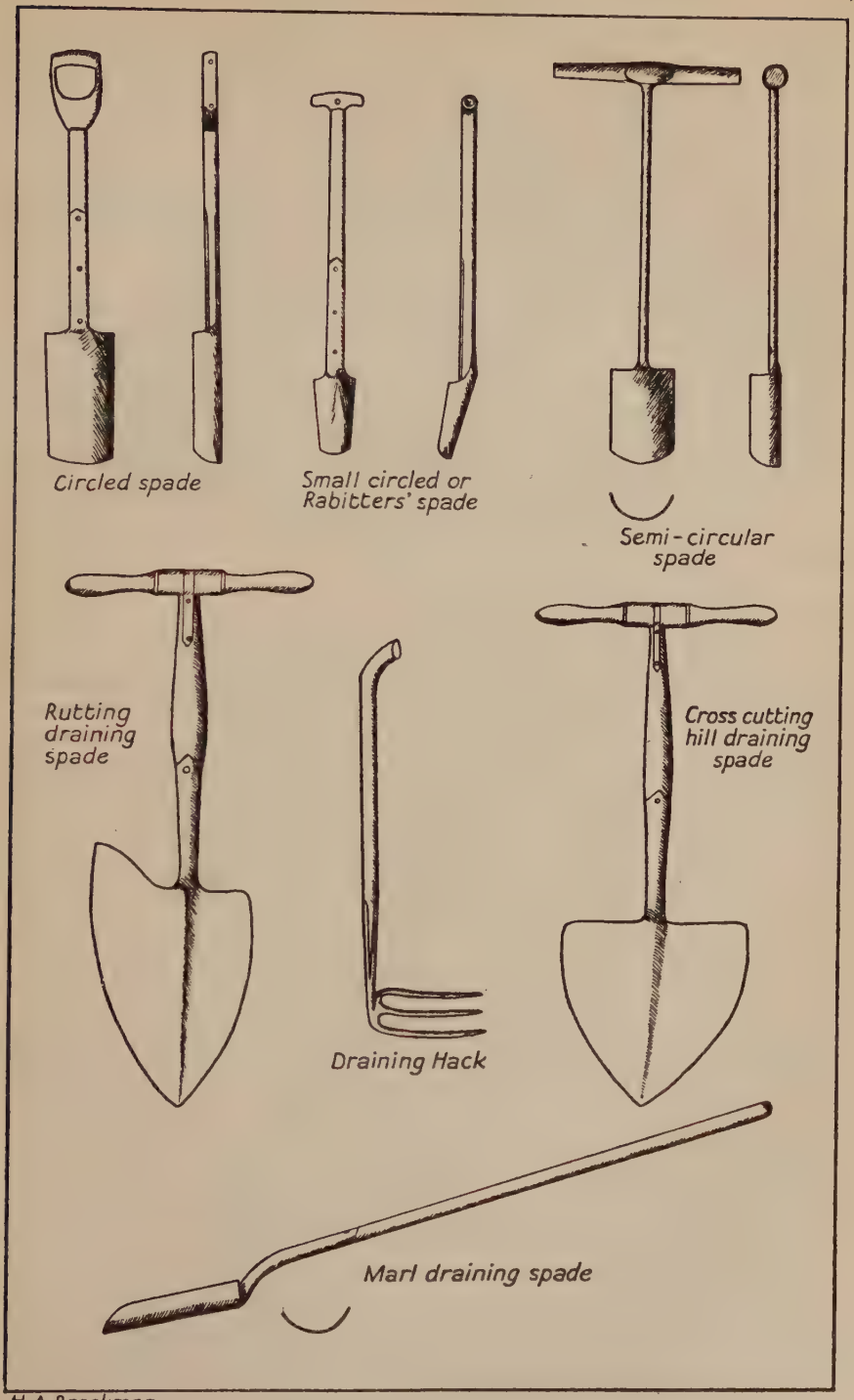
(6) *Small circled or Rabbiters' spade.* A small short spade weighing only a little over one pound. The handle is 29 inches long and of the cross-head pattern. The blade is 7 inches long and tapering from 4 inches at the top to 3 inches at the bottom. The 'dish' is very slight, being $\frac{5}{8}$ inch.

(7) *Semicircular spade.* Except for the cross-head handle this tool is an 'all steel' one. The blade is 10 inches long and 6 inches wide across the mouth, with a 'dish' of 2 inches. The sides are parallel, but at the bottom the blade is rounded off and not cut square across. The steel shaft is 28 inches long by $\frac{7}{8}$ inch diameter and has a certain amount of 'lift'. The wood cross-head handle is 24 inches long and $1\frac{1}{2}$ inches diameter tapering slightly from the centre, where it enters the steel socket, to both ends. The total weight should not exceed 7 lb.

(8) *Planting mattock.* This planting tool is of the ordinary shoulder-pick type, having one end pointed and the other flat. The pointed end is 9 inches long and tapering to a sharp point. Even if well worn it remains comparatively sharp-pointed all the time. The flat end is 7 inches long by 4 inches wide, and except for a small rounding off at the mouth it should be parallel-sided almost up to the eye, so that even when worn, full benefit may be got of the width. It is made in weights varying from 3 to 6 lb., but the latter is probably the most serviceable weight.

The following tools, though really in the first place draining tools, are so directly connected with mound or turf planting on peat that a description is desirable.

(9) *Rutting spade.* This is a large cross-head, two-handed tool. The handle is wood with strong iron straps riveted on both the back and front and continued over the centre of the cross-handle. The blade is 21 inches long, and as it is a 'one-way' cutting tool, the cutting side is winged, and both longer and deeper than the other side. The width at the top is 15 inches and the cutting edge tapers in a gradual curve to a fairly sharp point. The 'Kirrie' pattern is lop-sided also, but the cutting edge in this tool is straight, and it tapers to a very sharp point. The weight of the rutting spade is 8 to 10 lb., and it is made to be used with the right or left foot. The illustration shows a left-footed pattern.


Circled spade
Small circled or Rabitters' spade
Semi-circular spade
Rutting draining spade
Draining Hack
Cross cutting hill draining spade
Marl draining spade

H.A.Brookman

(10) *Cross-cutting or hill-draining spade.* The build of this tool is exactly similar to the above except that it is a two-way cutting tool, both edges being equidistant from the centre of the blade. It is made in several sizes, but the most useful one is 18 inches long by 16 inches wide at the top and tapering gradually to a fairly sharp point.

(11) *Digging fork.* The best type of fork for draining and mounding is the strong four-pronged box-handled one. The prongs are made of ½-inch steel, and are 12 inches long tapering to a point. The total outside width of the prongs is 8 inches.

(12) *Draining hack.* There are a great many patterns of draining hack, but the most suitable for peat, unless the drains are very deep, is the three-pronged one in which the prongs are made from oval steel of about ½ inch on the maximum diameter, and about 12 inches long, fitted with a short handle, 36 inches or 42 inches long, with a crook at the end for a hand grip.

(13) *Draining or Marl shovel.* The blade of this tool is 15 inches long by 7 inches wide with 1-inch 'dish', and is diamond pointed. It is used with a long handle, and the blade is set so that the workman can keep a 'straight back' when using it.

DESCRIPTION OF PLANTING METHODS.

The following are the main types of planting methods in use to-day: notching, pitting, mounding or turfing, and a fourth, mattock planting, which, for various reasons, is described separately, although notching, pitting, and mounding can all be performed with the mattock.

Notching. The idea behind this type of planting is to wound the soil with the minimum number of strokes (usually one or two) of a tool, and thus make an opening quickly which is of a sufficient size to take in the roots of small plants. This object is gained by the following three styles, the use of any one of which is determined by the physical structure of the soil worked over, or by local custom.

L and ⊥ notches. These notches are each made by two cuts with the Scotch pattern spade, the former to form the letter L, the latter the letter T inverted (⊥). In both notches the first cut is made in a line with the direction of movement of the worker by sharply striking the spade into the soil, and the second cut at right angles to it, treading the blade in to the required depth. In the L the turf is then prised upwards, and when high enough the left side of the raised turf is tilted over sufficiently to allow of the plant roots being passed into the opening, the plant being finally placed against the side of the first cut and near the centre of it. When the plant is in this position, at the correct depth, and still held in the hand, the turf is dropped and 'heeled in'. In the case of the ⊥ notch, after the spade has been well treaded in at the second stroke, the turf is prised upwards by levering down the spade handle, thus opening the first cut widely. The roots of the plant are drawn into this opened cut with the top of the plant at an angle slightly away from the workman, and, just as the spade is withdrawn, the plant is pulled forward and upward to

straighten up the roots and arrive at the correct position and depth. The dropped turf is then 'heeled in'. In both of these types of notching there is a certain 'trick', but after a few days' practice this is fairly easily acquired, the main thing being to get the first cut perpendicular and as deep as possible.

Vertical notch. This third style of notch is carried out with the Schlich or Mansfield spade, the former spade being specially designed for this notch on sandy soils. The blade is driven vertically into the soil to a depth of over 6 inches, and then pushed backwards and forwards several times till a fairly wide opening has been made. As only small plants should be used in this method the roots are readily placed into the slit, and to get the roots straight they are pushed down fairly deeply and then drawn up to the correct depth. The plant is then held in this position till it is fixed by pushing the spade into the soil parallel to the original cut, and about three inches away from it, in a sloping direction (handle towards the body), and then pressing these three inches of soil on to the first cut, thus closing it and fixing the plant. A repetition of this last stroke two or three times closes the series of openings, and the plant is 'heeled in' in the usual way. Great care has to be taken that the bottom of the first cut is closed as well as the top, otherwise the plant is fixed only at the collar and is 'hung'.

Pit planting. The ordinarily understood pitting implies the opening of a hole 12 to 15 inches square, stirring up the under soil well, and then carefully placing the plant in the centre with the roots evenly spread out, and finally fixing it by treading in the loose soil which has been thrown out. In large-scale forestry this is not practicable, but various modifications of this method have been practised and perfected, especially in recent years. The general principle is to open a pit of 6 or 7 inches diameter, and after taking out the plug, and stirring the bottom, to place the plant on the side of the pit and fix it there. For the large-sized pits the ordinary digging spade is the best tool, but for these smaller modified pits, the Irish, Mansfield, and circled patterns are best, with the semicircular in a class by itself for this work. It should be noted here that in pit planting there are two systems of carrying out this work, one in which the pitting and the planting are carried out as two separate and independent operations, the other in which the work is completed at one operation. Where pitting is done in advance with the Irish and Mansfield spades, a square pit, varying in width from 5 to 7 inches, is opened, the plug being laid at the side and the bottom of the pit thoroughly stirred, and when the planting is being done the plug can be put back whole or broken up. The usual practice, however, is to complete the planting at one operation, and in this case the quickest and best method is to cut only three sides of the pit, thus saving a stroke, and by prising the plug of soil up it is turned over this hinged portion on to the side of the hole. The bottom is then thoroughly stirred, and the loose soil used to steady the plant, thereafter cutting up the plug, filling in the pit, and finally 'heeling in' the plant. With the circled spade the procedure is exactly similar to the above, except that with the three strokes a round hole is made. For small plants on good open soil the small circled spade opens

pits very speedily. It is also most useful for beating up, because then the pit is opened on the site of the original one.

As already stated for pit planting the semicircular spade is in a class by itself. It is built and worked quite differently from the ordinary run of spade, and is outstandingly the best pitting spade the forester has to-day. There is considerable art in working it, and the exact movements are rather difficult to describe accurately. It is drawn up in front of the body, with the hollow side towards the workman, till the wood handle is almost level with the chest, and it is then driven sharply into the soil, sinking, usually, at this stroke to a depth of 3 or 4 inches, and is then swung from side to side, with the arms almost at full length, the body remaining more or less stationary. This movement is more or less similar to the swinging of a scythe except that there is a working stroke each way. By means of a very slight downward pressure during the above movement the blade is readily worked to a depth of 8 to 9 inches in any ordinary soil, and where pitting and planting are completed at one operation there is a hinged uncut portion left, as described for the Irish and Mansfield spades. The plug is prised out of the pit, and the bottom thoroughly stirred, this loose material being used to steady the plant, and thereafter the plug is cut up and treaded into the pit. Where pitting is done in advance the plug is cut all the way round and left on the top, the bottom being thoroughly stirred.

Mattock planting. This method has been kept separate, as it is distinct. It can be said to be the premier tool for planting steep slopes, just as the semicircular spade is so on level or gently sloping ground. The following three styles of planting with the mattock are those most generally in use. The first one is the best for steep ground; the second and third can be used where more or less level ground is being planted with this tool.

(1) Screef the surface lightly with the flat end, and then loosen up the patch with the pick end, and when this is completed drive the flat end into the side of the patch nearest the rising ground and draw towards the body. This forms a pit and before withdrawing the mattock the plant is inserted in it, so that when the mattock is taken out the plant is held against the near side of the pit, and loose soil is filled in from the higher side of the patch. Then level up and 'heel in' firmly. (2) The pick end is driven well down into the soil and sharply prised upwards, making a fairly deep cut. The soil on one side of this cut is thoroughly prepared with the pick end and then withdrawn so as to form a pit exposing the face of the first cut. The plant is placed against this and the loose soil pushed on to it and 'heeled in'. (3) To form a Γ-shaped notch, the pick end is used to make a fairly deep scratch in the soil, and then the flat end is driven in deeply at right angles to it. By prising up the blade a corner of the turf is raised sufficiently to allow a small plant to be placed in the opening, when the turf is dropped back and firmed up.

Mound planting. This is a method of planting with which the great majority of foresters have only become familiar in the last eight or nine years, notwithstanding the fact that on all types of soil, good, bad, and indifferent, the evidence has always been before us of the benefits derived by plants placed on

mounds of soil taken out of drains. Sir John Stirling-Maxwell was the first forester to take up this matter seriously, when he introduced mound planting at Corrour in 1908.

Mound planting is a method for use on difficult soils, and of these there are two main types, the leached, panny, moor soils of the east coast, and the peats of the west coast, and in both cases the method of attack is to plan an intensive system of drainage on the area under consideration, so that there will be sufficient mounds per acre on which to place the plants finally allotted. Where intensive draining and mounding are to be done it is usual to have the lay-out planned so that the drains are parallel, and an exact distance apart, and from each drain a certain number of rows of mounds are to be made. At a plant spacing of $4\frac{1}{2}$ feet with drains placed at 18 feet or $22\frac{1}{2}$ feet intervals, each drain will be required to supply 4 rows and 5 rows of mounds respectively; and with mounds 18 inches square by 6 to 10 inches deep, this is found to work out very well in practice. In regard to the actual draining, all the main drains and perhaps a small proportion of the side or subsidiary drains should be opened, if possible, at least two years in advance, and the final network not less than six months nor more than one year before the actual planting. It is absolutely essential, for economical draining and mounding on peat, that the correct tools be used, and also that the turfs be cut from the drains and placed in position in one operation. The two tools necessary are the rutting or hill draining spade and the draining hack, which have already been described. All mounds should be fairly well treaded down at the time of setting them out, so that they will knit quickly with the soil underneath.

With regard to the actual planting of mounds, this is done either by notching or pitting, and in the former method either the ordinary or the Mansfield spade is used to make a vertical notch; by the latter method a circled spade or a 4-inch diameter semicircular spade is the best for opening small pits. All species, even spruce, can with advantage be planted deeply on mounds.

THE ORGANIZATION OF PLANTING OPERATIONS.

Besides the actual method of preparing the soil for the reception of the plant there are three other phases of planting operations which are of importance, and these will be considered briefly before dealing with the comparative values of the various methods just described.

Accurate lining and spacing of plants. There is to-day a system of planting by which plants are placed in perfectly straight lines and at an accurate spacing in these lines, and the alternative system where the lines are not straight though quite distinct, and the spacings not accurately measured. In the former, poles are ranged in parallel lines at intervals of seven (or more) plant lines: thus at a spacing of 4 feet the poles would be ranged at 28 feet and at a spacing of 5 feet they would be 35 feet apart. The poles are always placed on a line of plants, and while work is proceeding on this line the three lines on either side are being brought forward at the same time. Alternatively the pole lines can be completed in advance of the main planting. The spacing in the lines is done

accurately with measured sticks. The two advantages of this system are that in the first planting the exact number of plants per acre is laid down, and then later, in summer weeding and beating up, the plants or blanks are more easily located. On the other hand it leads to more mechanical work and plants are very frequently badly placed, as on the edge of drains, close against roots or stones, or not placed to advantage as on the mounds from drains. Certainly the system of irregular spacing does not appear to be as methodical, but every man is trained to be on the alert to place his plants to the best advantage, and this should compensate for any loss of time in weeding and beating up. Probably a combination of the two is best, planting in more or less regular lines but allowing considerable freedom to the workmen as to the exact position of each plant. In this way workmen are encouraged to think, and will do so if allowed.

Care of Plants. This is an extremely important branch of the work. Plants in transport should be kept covered, and, immediately on arrival at the planting ground, should be heeled in where there is as much shelter as possible from drying winds. It is of first importance to untie all the bundles of plants as they are being laid into the trenches: leaving even a small number tied is too great a risk. In the handling of plants in the planting squad every precaution should be taken to prevent drying, either by the use of canvas bags or small wooden boxes with handles for carrying. It is quite common even to-day to find a planter carrying forty or fifty plants in his hand, quite uncovered and quite dry. There is no excuse for such carelessness, as the use of bags or boxes entails no additional work, and only the cost of such materials has to be considered.

Systems of Pitting (or notching) and Planting. Already a note has been made about pitting in advance and pitting and planting together. This matter will now be dealt with more fully. In the case of notching, the opening of the soil and placing of the plant must be done in one operation, and most frequently the planter carries and places into the notch his own plants, a squad of say ten or twelve men being supplied with plants by one boy. Where pitting is employed the workman can, as in notching, open pits and handle his own plants at one operation, but for this method of planting it is more efficient to use boys for the actual handling and placing of the plants in the pits. Where pitting is being done in advance, the planting is afterwards completed by boys who, after placing the plant, fill up the pit, using for this purpose a light spade, or garden trowel, or entrenching tool. The entrenching tool is the most serviceable one for this operation. Opening of pits in advance has the disadvantage, on the heavier and tighter soils, of the pits getting and keeping full of water, and on the lighter soils, if left open for any time, of the loss of loose soil by washing. This system, however, has the decided advantage of showing that every pit is opened to the required depth. So far as is possible pitting and planting should be completed in one operation, and the best way to do so is for each two workmen who are opening pits to have one boy, carrying a stock of plants, and placing and holding them in the pits till they are steadied. He does this alternately for each workman. In this

way, work is most economically carried out and, under close and trained supervision, any careless or shallow pitting is readily detected and stopped. Also work is more pleasant for both men and boys when they are kept together, and becomes less mechanical; the boys are, at this early stage, trained to the correct ways of using planting tools, which later stands them in good stead, as they usually prove to be the best type of forest worker, having had developed in them a considerable degree of forest sense, the possession of which is a prerequisite of a good planter.

COMPARATIVE VALUES OF THE PLANTING METHODS DESCRIBED.

Under this head the value of the various planting methods and systems described will be considered from the cultural and from the costing points of view. In respect of costings more or less definite figures can be given, but unfortunately the same cannot be stated for the cultural side, as on ordinary types of planting ground definite proof of the superiority of one planting method over another is not available. Work has commenced on this but is not yet far enough advanced, but there is little doubt that the extra care taken in some of the methods is reflected in the greater vigour and health of the plantation. On certain soil types, however, for example the poorer peats, the advantage of mounding, for instance, has been proved.

As a basis for costings, 1,000 plants will be taken as the unit, and in wages that of 6*s*. for a man and 3*s*. for a boy per day. The costs will be for actual planting only, exclusive of supervision, heeling in of plants, transport, &c., all of which are common to each method.

Notching. The various types of notching described are in general use to-day. From a cultural point of view this method should be kept strictly to the more open soils, such as sand and sandy loam, and even then supervision will require to be close, as it lends itself to certain types of careless work. On soils of a heavy or tight nature such as clays, podsols, and some peats the plant roots get flattened out and compressed in the cut and very frequently also are badly bent. Of the three types probably the L is the best, but it cannot be made on very light soils such as pure sand. The vertical notch should only be used on pure sand. Notching, however, has the advantage of being speedy and cheap, as a man can plant 600 to 900 plants per day or more and can average 650 per day for the season, with one boy supplying plants to 10 or 12 men. Thus the complete planting costs work out at 10*s*. per 1,000 plants.

Pitting. On the great majority of soils pitting is the method of planting which should be adopted, the only exceptions being those of a light sandy nature and the poorer difficult types. For this method of planting the semicircular spade should be generally used, as there are very few types of soil on which it cannot be worked with speed and efficiency. The Mansfield pattern can be used with advantage on very stony soils, and on rocky ground with only pockets of soil; it is also the best tool for breaking iron pan and thoroughly stirring up those grey leached soils found so commonly on the east coast. The cultural advantage of even these modified forms of pitting are evident to the

experienced and observant forester forming plantations on any average forest soils. With regard to costs it is found that an average workman skilled in the use of the semicircular spade can plant 450 to 650 plants per day, this with the assistance of one boy who, however, gives plants to two men only. Therefore 500 plants per day is the average for the season for one man and half a boy, and this works out at a cost of 15*s.* per 1,000 plants. On the more difficult types of stony and impervious soils work is somewhat slower. A man and half a boy would average for the season 450 plants per day, working out at a cost of 17*s.* per 1,000.

Mattock planting. As already indicated this type of planting is only adapted for the very steepest slopes with perhaps one exception, that of poor, thin, hard, moorland soils, on which the mattock might prove more useful than any other tool, as by it a good-sized patch is thoroughly broken up, thus improving it as far as possible for the reception of the plant. Culturally, on steep slopes, there is no advantage in the use of the mattock, as a pit is formed similar to that made with a spade: the advantage lies in the handiness of this tool due to the physical character of the ground. The cultural benefit of using it as described on poor moorland is evident. Mattock planting should never be practised on any but the above two types of ground, and this being so it is slightly slower than the ordinary methods, but on slopes with a reasonable depth of soil costs would work out at a similar rate to those stated for difficult soils under 'Pitting' at 17*s.* per 1,000. On difficult slopes and on poor moorland, costs would work out at the rate of 19*s.* to 20*s.* per 1,000 plants.

Mound planting. From the cultural point of view this is a method of planting which, on peat types of soil, leaves no room for doubt as to its advantages. It is at present being mainly and pretty extensively tried on fairly difficult types, and experimentally on the worst or rawest types. On any wet bog, even the poorest, drainage has a beneficial effect, and the object aimed at is to combine draining and mounding to enable a crop to be established with the least possible delay. It is quite useless to plant on mounds without thorough drainage, and on the other hand improvement of the bog, even after heavy draining, is so slow that plants are held in check for many years. The peat on the mounds begins at once to decompose, making available plant food so that the young trees make some headway, even in the first season after being planted, and the improvement effected in the solid peat, though much slower, is anticipated to be sufficient, when the crop comes to demand it, to enable growth to be continued without any marked check. In most cases the benefits of mounding are evident, but there is doubt at present, with our existing knowledge, as to the ultimate changes to be effected in the peat *in situ*. Regarding costs, as mound planting is a dual and a comparatively recent operation, exact costing is not available, but the following figures can be relied on as being near enough for practical purposes. On the poorer classes of land, where intensive draining would be necessary, the final costs of the draining and mounding at 5 feet would work out at from £3 to £6 per acre, depending on the character of the soil and the width between the drains. These prices would allow for drains placed at

intervals of one-third to one-half a chain apart and include the cost of opening, ranging from 2*s*. 6*d*. to 4*s*. 6*d*. per chain, plus 6*d*. to 1*s*. per chain allowed for laying out the turfs. There are classes of soil where drains will function efficiently at wider intervals than those stated above, and on such, after the material from the drains has all been used up, mounds can be cut from the solid peat, thus leaving a pit at the side which can do no harm. By this system costs are reduced considerably and might range from £2 to £3 per acre. The actual planting on mounds should not exceed 10*s*. to 15*s*. per 1,000 plants.

To arrive at the final cost per 1,000 plants for mound planting, and thus be able to make the figures for this method more or less comparable with those stated for other methods, it is usual to charge so much of the work against draining, ranging from perhaps 50 per cent. to 25 per cent. Thus on (*a*) the more intensive drainage a charge of say 50 per cent. would be made against draining and 50 per cent. against mounding, but on (*b*) the less intensive, only, say, 25 per cent. against draining and 75 per cent. against mounding. Such proportions are only approximate and would require to be determined for each s heme. Using the above figures, however, as a basis the following costs are arrived at for a spacing of 5 feet:

(*a*) Allowance for mounding 18*s*. to 36*s*. per 1,000 (plus 12*s*. for planting), giving a final cost of 30*s*. to 50*s*. per 1,000 plants.

(*b*) Allowance for mounding 16*s*. to 27*s*. per 1,000 (plus 12*s*. for planting), giving a final cost of 28*s*. to 40*s*. per 1,000.

Summary. By bringing the costs of the various methods together the difference between the two extremes is better realized.

Notching costs 10*s*. per 1,000 plants.
Pitting costs 15*s*. to 17*s*. per 1,000 plants.
Mattock planting costs 19*s*. to 20*s*. per 1,000 plants.
Mound planting costs 28*s*. to 50*s*. per 1,000 plants.

Although notching is much the cheapest method it should never be used except on the most open soils. For planting on average forest soils pitting should be the invariable practice, using the semicircular spade on flat or gently sloping ground, and the mattock on steep slopes. Mound planting, though expensive, has come to stay, as only by this means can the bulk of the peats be taken into cultivation.

Methods of the future. There is little doubt that in the near future more mechanical means of soil preparation for planting will be adopted. To-day certain progress has been made in this direction, and as soon as the experimental stage is sufficiently far advanced we may expect to find that on peat, drains will be opened and turfs cut with a machine, and on the dry moorlands, regularly close-spaced ridges thrown up by the plough. This cannot come too soon, but on the majority of forest soils planting will go on with the hand tools of to-day and yesterday. The one thing which requires to be encouraged, because there is considerable room for improvement, is the 'forest sense' of those of us who are and will be employed in the actual operations of planting.

THE BEARING OF SOME ECOLOGICAL CONCEPTIONS ON THE FORMATION OF PLANTATIONS

BY H. M. STEVEN

INTRODUCTION.

ONE of the outstanding features of botany during this century has been the rise of Plant Ecology as an organized science with an increasingly voluminous literature. Although a new science, much of it is only a fuller flowering of conceptions which have been slowly formed, particularly in silviculture, during the centuries since the rise of systematic forestry. Thus the forester coming for the first time to Plant Ecology finds much which is not new to him. In its early and undifferentiated development, ecology owed some debt to silviculture, but it is now in a position to repay that debt as a result of the great advances which have been made, particularly in basic conceptions.

Plant Ecology, the study of plants in their natural homes, obviously has the closest connexion with natural forest communities. Its bearing on the artificial formation of plantations is less direct, but much help can undoubtedly be got from viewing the problems which this branch of forestry is presenting from an ecological standpoint. In this article only the bearing of certain broad ecological conceptions will be considered.

THE CLIMATIC CLIMAX AND THE INTRODUCTION OF EXOTICS.

Forestry in Great Britain is being based more and more on the use of trees not indigenous to this country. The indigenous species such as oak, beech, and Scots pine are all being planted or regenerated on a small or decreasing scale. This tendency is also to be noted in many other parts of the world, for example, South Africa and New Zealand. What light can be shed on the probable results of this by the basic ecological conception that each region has a climatic climax which marks the end of the development of its vegetation in the absence of interference?

In Great Britain we have two forest climaxes. Firstly, the Deciduous Summer Forest in the lowlands and lower hills of England, Wales, southern and eastern Scotland, which is a type dominated mainly by oaks, but beech, ash, and other species are important under certain conditions. Secondly, in central and north-western Scotland we have an outlier of the northern European Coniferous Forest, in which Scots pine is the most important tree, but the birches are also prominent.

From a forestry point of view the sites of the natural climaxes have had three different histories. Firstly, a forest type may have persisted until the present day in a form not notably different from the natural climax. Tansley and other British ecologists consider that many of the woodlands of England are of this semi-natural type. Secondly, the natural climax or semi-natural wood may have been replaced by an entirely artificial forest community, say

a stand of European larch on an oak woodland site in the south of England. Lastly the original climax forest may have been changed into arable land, grassland, heath or peat moor, and after a long or short period as such a forest community has been re-established. As a rule such communities have been artificial, differing more or less materially from the climatic climax.

The second, and to some extent the third, type of development has occurred during the last two centuries. In the first place Scots pine began to be planted outside the Northern Coniferous Forest region, then European larch and Norway spruce were planted, while during the last half-century Japanese larch and Western American conifers have been used to an increasing extent. The post-war afforestation by the Forestry Commission has been largely on the third type of site, namely, grassland, heath, and peat moor.

In general, experience in this country has shown that forest communities differing markedly from the climatic climax can be successfully established, for example, coniferous communities in Deciduous Summer Forest regions. By force of circumstances, this country is committed to the principle that timber must be a cultivated product, like practically all other plant products, from potatoes and wheat to oil palms and rubber, but with this difference that the maintenance of the forest should be secured with the minimum cultivation. It appears also that this will be the final conclusion over large tracts of the world as the result of continued uncontrolled exploitation, and the great difficulty in applying naturally the principle of sustained yield to the valuable species, especially in complex tropical and sub-tropical forest communities. If this is accepted, how far can one safely depart from the natural climax, if this is desirable economically, in creating the cultivated forest?

Let us consider the nature of the climatic climax. Clements in *Plant Succession and Indicators* defines the climax thus: 'Every complete sere ends in a climax. This point is reached when the occupation and reaction of a dominant are such as to exclude the invasion of another dominant.' This climax may not be reached owing to soil, reaction, competition, migration barriers, and man, and we then get a sub-climax. Tansley and other British ecologists consider that the status of climax should be given to such sub-climaxes if they are relatively permanent, and this appears to be the better definition. For example, consider the importance of migration barriers. It must be largely a matter of chance whether or no particular dominants reach a given region, especially a detached region such as Great Britain. If this country had not been cut off from the continent, we would probably have had Norway spruce in one of our climatic climaxes. One can take this idea of migration barriers farther, however. The western seaboard of Great Britain is similar in climate to the coast of British Columbia; yet the climaxes are entirely different. In the latter region the reaction of physiography and the ice age resulted in the reinvasion of an exceedingly rich tree flora, particularly of conifers, while in this country our post-glacial forest communities are poor, even relatively to the continent of Europe. The Deciduous Forest only reaches scrub size under some of our conditions, while our only coniferous forest tree, Scots pine, is adapted in its

general growth to a continental rather than an oceanic climate. It can reasonably be argued, therefore, that chance acting through migration barriers in a wide sense largely determines the composition, hence to some extent the type of climax, because it is from definition largely a matter of competition between the available units. It may be argued that the Western American conifers will not compete naturally with the existing climax communities in this country. That has certainly yet to be proved, but it was interesting to see *Pinus pinaster* establishing itself, regenerating, and ousting the native vegetation, in the 'Mediterranean Climate' of the Cape Peninsula in South Africa, and there are no doubt many other examples to support this thesis.

The view is put forward, therefore, that there are some grounds for considering that the introduction of exotic trees is an effort to overcome migration barriers. Forestry is a commercial proposition, hence the forester, if he has to deal with climaxes unsatisfactory from an economic point of view, must seek better ones. In doing so he is not necessarily transgressing the general theory of climatic climaxes; he may be merely presenting Nature with new bricks to build a new and better climax, at least from an economic point of view.

Where exotics have been introduced scientifically, this idea has been worked out in practice, because the criterion taken has been similarity in climate between the region where the tree was indigenous and its new home. The practical difficulty is to assess climate. This is a large and productive field for inquiry from the point of view of the introduction of trees.

The conception of climatic climax has, however, both warning and help to give in this connexion. Even the simplest climax is exceedingly complex, and the picking out of one unit from the climax and endeavouring to create a new community with it cannot but be hazardous. For example, it is now being realized that care should be taken to introduce also the normal mycorrhiza which is so often associated with a tree species. Again, the stability of the soil type associated with the climax may depend on some other unit or units in it than that introduced. It has been suggested that one should not only introduce the trees but also the shrubs and other associated vegetation. There is much to recommend this in theory, but it is unlikely ever to be practicable, and often will be unnecessary or indeed dangerous, by increasing the chance of introducing rust fungi.

Nevertheless, it would be a great advance biologically and economically if species were not considered as isolated entities, but as units in a complex community, and this consideration led to a detailed study being made of the climaxes or climax formations which contain important forest trees which have been or may be used widely outside their natural distribution. The introduction of exotic trees has now become so important that it is by no means premature to have organized investigations of this kind on an adequate scale. With the present largely haphazard methods, it is not a matter for surprise that there are failures, but rather that there have been so many successes. Much time might be saved and large economies secured if more were known regarding the best criteria of climate, the interaction of species on species, and the community

on its habitat in the ecological sense as the sum of the effective environmental conditions. Such data would enable a much more rational use to be made of trees outside their natural homes. For example, in this country the use of Scots pine and the European exotics in the Deciduous Forest regions frequently results in the degradation of the soil-type from a Brown Earth to a podsol. Even with existing knowledge this need not take place. If the known role of broad-leaved species, such as birch, in making for soil stability in coniferous communities was more widely realized and use made of it, then such communities would tend to become more harmonized with their new habitats with all the resulting advantages.

EDAPHIC ASSOCIATIONS AND SOIL IMPROVEMENT.

The term edaphic association is used by Tansley and other British ecologists for relatively permanent communities which do not reach the climatic climax owing to soil conditions, and the status of a climax is given to such communities. The factors which arrest development may also modify the site in the direction of increasing the stability of the existing state of development. For example, the Heath Association may be a climatic climax, as in very exposed sites and at the higher elevations in this country, but it may be an edaphic association, i.e. an arrested stage of development due to soil conditions. The nature of the humus produced by the heath plants results in a continuous leaching action on the soil, so that heavily leached podsols with or without pan are produced, decreasing the chances of the further development of the vegetation towards a tree climax. Again on peat moors the growth of *Sphagnum* and other mosses by increasing the water content makes for the stability of such communities. Clements, on the other hand, considers such edaphic associations to be sub-climaxes only. He recognizes these two reactions which retard succession, but thinks that these sub-climaxes are due wholly or partly to the action of man.

This is a matter of prime importance in afforestation in this country, because two of the largest types of land available for afforestation are the heaths and the peat moors. The planting which is proceeding on them is a large-scale ecological experiment, and can usefully be viewed as such.

It is important from the afforestation point of view in this country to keep in mind that the heath communities differ in status. In the first place we have heath communities at the upper elevations and in the most exposed regions generally which constitute the climatic climax, exposure being the limiting factor to any further development; this is the Heath Association, using the term association in the American sense of a climax unit. Secondly, there are heath communities which are but a stage in the development to pine forest. In this instance the heath communities are seral units, and Clements would apply the term heath *associes*. This is a very important type in this country. For example, many of the upland heaths, or so-called grouse moors, within the Northern Coniferous Forest in Scotland are of this type. Their development is arrested, either by the absence of pine in the immediate vicinity, or more frequently by periodic burning of the heather and other heath plants. Never-

theless, a feature of many of these heaths, for example, in Deeside and Strathspey, is the scattered young natural pines often far from existing pine woods, hence the term 'crow planted'. Again the heaths in the south of England, for example, on the Bagshot Sands, are often readily colonized by Scots pine from adjacent trees or plantations. Although Scots pine is not indigenous to England, it was so in post-glacial and prehistoric times, and it is difficult to understand how it was ousted from the heaths, which it so readily invades and on which it establishes itself, by competition with deciduous forest. It is interesting also near Bagshot, Surrey, to see *Pinus pinaster* regenerating and maintaining itself in competition with Scots pine. In this type of heath community afforestation is relatively simple provided one is satisfied with Scots pine. In the third category, namely, heath communities which may be edaphic associations, i.e. development to forest is impossible owing to soil conditions, the position is somewhat different. It is still a matter of doubt whether there are any heath communities in this country which can really be called edaphic associations, but the difficulties which are being encountered in the afforestation of some such areas lend support to the reality of this view. An example of this type is the flat East Yorkshire moor country. Elgee considers that these have always been open heath at least since the Bronze Age times. They are generally at an elevation of about 700 feet, and although exposed, this factor cannot explain in itself their arrested development. Typically these moors are poor floristically. *Calluna vulgaris* is the dominant plant associated with *Erica tetralix*, *Erica cinerea*, and a little *Scirpus caespitosus* and *Molinia coerulea*. *Cladonia sylvatica* and *Hypnum cupressiforme* are usually abundant. The soil type is a podsol, typically 2 to 4 inches of heather peat, on 4 to 8 inches dirty grey leach sand, loam, or sandy clay, at which depth there is a very thin pan which may be a typical iron pan or a soft humus pan, and which generally marks the limit of the penetration of the roots of the heath plants. The C horizon is a bright yellow or orange sand or sandy clay, and the geological formation from which it is derived is either Middle or Lower Calcareous Grit, a siliceous sandstone. Here as on most heaths it is uncertain how far periodic burning has been a factor in maintaining the stability of the heath community. Burning certainly causes considerable changes in the vegetation temporarily, and probably in the direction of rendering the conditions less suitable for trees. In the absence of competition from the *Calluna*, *Scirpus* and *Molinia* become more vigorous, and the lichen and *Hypnum* are replaced by *Campylopus flexuosus* and the alga *Zygogonium ericetorum* which forms a film on the surface of the peat. Nevertheless, if the view is correct that these heaths have persisted for several thousand years, then burning cannot be the entire explanation. One can understand that colonization by the native deciduous trees from the surrounding dales might be difficult because of the soil conditions, hence the spread of Scots pine from plantations formed in the surrounding and better areas during the last fifty years or so is of interest. There are to-day scattered natural Scots pine on some moors, but these grow very slowly and the root development is extremely superficial and largely confined to the A horizon of

the profile. It appears doubtful if one would ever get more than open pine scrub naturally, hence these heaths are, if not from a strict ecological then from an economic point of view, edaphic associations. The three soil factors which probably arrest development to a tree climax are the extremely fluctuating nature of the soil moisture—very wet in winter and dry in summer—as the consequence of the presence of the pan, the limited quantity of nutrients in the A horizon, and the poor aeration and causes arising from this which the peat causes. During the development of vegetation to a climax the conditions generally become more mesophytic, because the higher life forms are of this type, i.e. wet sites become drier and dry sites moister. Hence any means which will tend to stabilize the soil moisture content in these moors is likely to be beneficial. The rupture of the pan will tend to permit drainage downwards in winter and the rise of subsoil water in summer, the pan in this case being too near the surface to form a reservoir for ground water. The ploughing, therefore, by caterpillar motor tractor which the Forestry Commission is carrying out can be expected to render the site much more fitted for tree growth, because in addition to any stabilization of soil moisture, the C horizon, rich in potential nutrients, is mixed with the A horizon, and aeration conditions will be improved. Whatever forest community is ultimately found to be best for this type, it is almost certain that a broad-leaved species should be a constituent of it to slow down, if not prevent, further leaching.

The extensive peat moors in this country, particularly on the western side of it, present one of the most important afforestation problems of to-day. As is well known, many of the older and deeper bogs, say over 2 feet, contain strata of tree remains, while the pollen diagrams which have been made for many of our bogs have added much to our knowledge of the post-glacial immigration of trees into our island. In England and Wales birch is the principal species found in the bogs with oak less common, while in Scotland pine is much more abundant with the birch. The balance of evidence for many of these communities is in favour of the view that the stratification of the bogs which shows tree and other horizons indicates fluctuations in climate during post-glacial times. But when once bog forms it tends to perpetuate itself, owing to the conditions becoming progressively unsuitable to higher plants. Even although the existing climate no longer favours the rapid growth of *Sphagnum* and other mosses, and the conditions become drier, they are still usually unsuitable for tree growth, owing to the effect of the accumulation of peat. Many of these communities can, therefore, probably be considered edaphic in that the soil conditions, in a wide sense, prevent the climatic climax of the region being reached naturally.

In many parts of the country there are extensive tracts of land covered with only a thin covering of peat, much of it in still active growth. This newer peat has probably been formed since the forest was destroyed in historic times. The well-known effect of the destruction of forest in increasing the moisture content of the soil in moist climates owing to decreased transpiration, is probably the cause of this extension of peat communities. At present this type of peat

moor is becoming progressively more unsuitable for further development naturally to a tree climax.

The known difficulty of the afforestation of many different peat communities is to be expected, therefore, on general ecological grounds. Wherever *Sphagnum* spp. and similar mosses are in active growth, drainage must be the basic operation to secure further development, but the most useful suggestion which is given by the ecological standpoint is the use of birch—*Betula pubescens* is probably the best species in most instances—either in admixture with conifers or as an advance crop. There are also possibilities in the alders both *Alnus glutinosa* and *A. incana*. The climatic climax of the regions where many of the bog communities are found is usually birch forest, or at least birches would be a prominent constituent of it. Where *Calluna* is not prominent it would be comparatively easy to establish spruce when once birch was growing, and these two species might have constituted the climatic climax if spruce immigration had taken place naturally. In the extreme oceanic climate of many parts of the west side of the country the promising results obtained with Sitka spruce are interesting ecologically in view of the similarity of the climatic conditions between these regions and its home. Wherever *Calluna* is a prominent constituent of the vegetation, a pine species will almost certainly have to be at least a constituent of any successful forest community. In this connexion another Western American species *Pinus contorta murrayana* is promising.

SUCCESSION AND THE USE OF NURSE CROPS.

One of the most important advances in Ecology has been the working out of the theory of Succession and the application of this conception to particular formations. As is well known, the idea underlying succession has been in existence for several centuries, but recent workers, particularly Clements, have developed and systematized it. The feature of succession which it is desired to stress here is that while development proceeds, say in primary succession from a bare soil to the climax, the site is, in general, becoming more and more favourable to the higher plant forms, for example, where the climate permits, the climax is forest. As already mentioned the conditions usually tend to become more mesophytic, humus is formed and shelter increases, thus decreasing evaporation and giving protection from frosting and sun-scorch.

When a forest is to be established artificially on non-forest land, it is well to consider whether forest is likely to be but the next step naturally in the development of the existing community, or whether a jump is being made over several intermediate stages. If the former, then establishment is likely to be easy; if the latter, then difficulties may be expected, and special means may be necessary to secure success. For example, on the type of heath which normally develops to pine forest, the establishment of Scots pine and even other pine species is relatively easy. The position is somewhat different, however, in the case of beech. Watt has shown that while natural invasion of grassland by beech does take place, the normal sequence is through scrub—*Crataegus monogyna* often being the pioneer plant—ash and oak, to a woodland with

beech as the chief constituent and oak and ash subsidiary, finally culminating in the beech consociation. As foresters know, beech is frequently killed or severely damaged by sun-scorch and frost on open grassland, and probably is also sensitive to soil conditions, so that some advance growth of scrub or forest is necessary for its successful establishment, unless in specially favourable conditions. The practice, therefore, of the use of an advance nurse crop, say European larch, is based on certain biological requirements of beech, which must be provided for. Again the spruces are not generally pioneers in forest invasion, because of their sensitiveness to frosting, and their dependence on surface humus conditions as the consequence of their shallow rooting habit. The use of birch, pines, and other nurse crops planted either with or in advance of the spruces will, in general, greatly facilitate their successful establishment, by rendering the climatic and soil conditions more suitable to them.

In many instances, therefore, the establishment of economic tree communities on non-forest land means the leaving out of intermediate steps which play a part in improving the habitat, and there is undoubtedly need for wider use of nurse crops than has yet been realized in afforestation in this country. When once these tree communities are established, the probability is that the same difficulty will not recur when their regeneration artificially or naturally has to be carried out.

SUMMARY.

1. The introduction of exotic trees is considered in relation to the ecological conception of the climatic climax. Stress is laid on the fact that chance, acting through migration barriers, is important in determining the species in a climatic formation. The introduction of exotic trees can be viewed as an effort to overcome migration barriers, provided a selection is based on similarity of climate. There is room for investigation to determine the best criteria of climate in this connexion. In the introduction of exotics it would be an advance if the tree was not considered as an entity, but as a unit in a complex natural community, and if this was studied in advance.

2. The reality of the conception of edaphic associations in Great Britain is discussed with reference to heaths and peat moors. The varying status of heath communities is stressed, and the importance of soil improvement is discussed, particularly by ploughing on heaths where soil conditions are probably the limiting factor to further development. Peat moors are considered as an edaphic association.

3. The progressive improvement in habitat which takes place during succession is considered in relation to nurse crops where the establishment of an artificial forest community is made on non-forest land. Where the forest community marks the next stage in the development of the existing community nurse crops are not necessary, but where several intermediate steps in the natural development are being left out, or where the species in the proposed forest community are known to be sensitive to adverse climatic and soil conditions, then the much wider use of nurse crops is recommended.

THE SEASONING OF TIMBER

BY S. T. C. STILLWELL

Officer in Charge of Seasoning, Forest Products Research Laboratory, Princes Risborough

AS soon as a tree is felled and lies exposed to the air the process of the seasoning of its timber begins. The most obvious feature of the process is the loss of moisture which takes place, and this is accompanied by increase in lightness, strength and stability. No doubt chemical changes of varying degrees of complexity may also occur simultaneously with the drying and these are often claimed as especially beneficial to the qualities of a timber, but it is almost certain that for most practical purposes their effect is quite secondary and that the seasoning process is essentially one of drying.

The moisture in the timber which is to be dried out during seasoning may be divided into two categories according to its distribution. A part of it is associated with the wood substance itself which, before drying takes place, is saturated with what is often called absorbed or cell-wall moisture. The remainder occupies portions of the cell cavities and intercellular spaces and is termed free moisture. The loss of the free moisture marks the first stage in drying at any point in the wood, and it is not until this moisture has all gone and the stage known as 'the fibre saturation point' is reached, that the cell-walls begin to dry. There is an important difference in the drying out of the two classes of moisture. The loss of the free water causes no structural differences, but as the cell-walls dry they tend gradually to contract, and it is this fact which makes the operation of seasoning a difficult one.

In the drying of a block of wood the moisture at and close to its exposed faces evaporates first, and after a time, the free water in a thin layer at the surface having dried out, the moisture in the cell-walls begins to leave and there is an increasing tendency of the affected layer to shrink. Due to its connexion to the adjoining inner portions of the wood which at this stage still have their free moisture and have as yet no tendency to alter in size, the drying surface layer cannot shrink freely, and as a result of the restraint, stresses which tend to stretch the surface portions and compress the interior are set up in the wood. Stresses of a similar nature, due to moisture differences existing in adjacent layers and portions, persist throughout the drying, though, of course, they vary in intensity from point to point in the block, and from time to time during the process. When they become excessive in amount they are the cause of the checking, splitting, and other defects which commonly occur during seasoning. When they are kept within suitable limits, however, they are not harmful and the main problem of seasoning is to consider how they may be kept within bounds. It is necessary, therefore, to see what conditions affecting the drying and drying stresses can be used for this purpose.

One fact of the greatest importance is that when exposed to the atmosphere,

timber will not dry below a certain point, which depends on the temperature and even more so on the humidity condition of the surrounding air. When this point is reached, there exists a state of equilibrium between the moisture in the timber and that in the air; and to any hygrometric state of the air there corresponds a definite moisture content in the timber at which a stable condition can exist. This need not be discussed further than to say that corresponding to the full range of humidity conditions from saturation to dry air, the moisture content values which give equilibrium extend continuously from fibre saturation point to complete dryness.

Reverting to consideration of the progressive drying of a wooden block, the stress in the surface layer will increase as this portion dries relative to the adjacent tissue. Two factors, however, tend to set a limit to the drying and consequently to the stress. On the one hand, when the surface layer begins to lose its cell-wall moisture, a slow flow of moisture sets in to it from the interior and this flow increases as the layer becomes drier. On the other hand, the drier the surface layer becomes and the more nearly it approaches the moisture condition at which, were it not for the flow to it from the interior, it would be in equilibrium with the hygrometric state of the surrounding air, the more slowly will it give up moisture to the atmosphere. After a time, therefore, a stage will be reached at which the gradually lessening flow of moisture from the surface of the block to the air is equalled by the flow of moisture from the interior, and then the surface layer will not dry further. It will be clear that the surface moisture content at this point will in general lie somewhat above the equilibrium value corresponding to the surrounding air. Both the limiting condition of dryness of the surface layer and the maximum stress in it will depend therefore on the condition of the surrounding air, and more particularly on the humidity as has already been stated. Since if the air is fully saturated, the surface will not dry below fibre saturation point, at which no drying stresses will exist, it follows that if the humidity of the air in contact with the block be made sufficiently high, the stress in the surface layer can be kept as small as is necessary or desirable. The humidity of the surrounding air becomes therefore a most important factor in drying and indeed the accurate control of air-humidities which is possible in good kiln-seasoning practice is one of the main technical advantages of that process.

It has been shown already that under any conditions of drying there is a limiting value to the stress set up in the surface layer, and this occurs when the internal flow from the central portion of the timber to the surface is equal to the loss from surface to air. Under these conditions of stress, therefore, the drying of the block must be equal to the rate of internal movement of moisture from centre to surface. If, as is necessary, the stress is to be confined within safe limits by suitable adjustment to the hygrometric conditions of the surrounding air, the rate of drying—except for a relatively short time at the start—must conform to the rate at which moisture can move within the timber itself under the external conditions demanded. To increase the rate of drying of timber with safety, therefore, it is necessary that the rate of

internal movement should itself be increased, without disturbance of the relations between the timber and its surrounding air. This can be effected by carrying out the process of drying at a higher temperature, and, though for most species there is a limit of temperature beyond which it is impossible to go (probably on account of the weakening effect of heat on the timber and a consequent reduction in the value of the safe drying stress), yet this fact is made use of in kiln-drying practice to reduce the drying time to a small fraction of that necessary at normal air temperatures.

The parts played by temperature and humidity in drying have now been discussed. Looking at the matter in a slightly more practical manner, a further consideration arises. The moisture which is dried from the timber needs heat for its evaporation. This is taken from the surrounding air, which also receives the evaporated moisture. In a short while the air near the surface of drying timber will be cooler and its humidity will be higher than at first, and as a result the rate of drying will fall off and ultimately cease. This can be prevented by bringing a fresh supply of air into contact with the timber, and indeed, in practice, a movement of air over the surface of the drying material is relied on to give continuity to the drying process. One aspect of air movement or circulation is of the greatest importance in practical work. Where the same air passes over a number of drying boards in succession as generally happens, it gradually becomes cooler and wetter as it proceeds, and therefore less effective for drying. For this reason there will be a difference in the drying rates of the successive boards, a difference which as between any two will depend on the rate of air movement and the intermediate distance (in terms of drying surface) as well as other factors. The faster the circulation and the less the intervening distance between them, the more nearly will two boards of the sequence dry at the same rate.

Turning more fully to the practical aspect, it is desirable to consider how the three important factors of temperature, humidity and circulation enter into the main processes of air- and kiln-seasoning by which timber is commonly dried for use.

In air-seasoning[1] both the temperature and humidity of the available air are dependent on local climatic conditions. The temperatures at which the drying is carried out, therefore, fall as a rule far below the limiting values which have already been discussed. In themselves, they are unlikely to affect the timber adversely, though in so far as they determine the rate of drying they may extend the time of drying to unnecessary lengths. Humidities, on the other hand, may quite well be such as to damage the timber, and it is well known that freshly sawn oak exposed to a drying wind will check freely in the course of a few hours' time. Humidity control is therefore necessary and this is brought about by variation of the third factor, circulation. It has been shown that the humidity of air increases as it passes over drying boards, the more rapidly as its velocity is less. If, therefore, the movement through a pile or stack of timber is made sufficiently slow, any adverse effect from too low

[1] See also *Forest Products Research Special Report*, No. 1.

humidity may be confined to as short a distance from its entrance as is desired. This fact is made use of freely and the necessary control of air movement is effected in various ways, by the use of narrower sticks to separate the layers of piled timber, by increasing the width of the timber stacks, by varying the orientation of the piles in relation to prevailing winds, by narrowing the distance between adjacent piles when these are grouped together, or by sheltering the timber within enclosed buildings or sheds. Circulation being dependent, though in no obvious or direct manner, on winds and draughts, is itself an uncertain factor and its control in any precise sense is out of the question. To ensure safety of the timber, protection is generally carried to unnecessary lengths and this leads to slower drying and the further extension of what at best is a relatively slow process, or to insufficient drying and the troubles which so frequently follow from the use of timber in too green a state.

The economics of air-seasoning are directly affected by the long periods required to dry the large stocks which are necessary to ensure continuity of supply. The interest on the capital value of the timber, the cost of insurance and the rent, rates, and other charges on the space or buildings which it occupies are important items in the cost of drying. As compared with the more rapid kiln-drying, air-seasoning allows less advantage to be taken of market fluctuations, and this and its dependence on climatic conditions must be reckoned against it. It is important, too, to remember that for many uses it is an incomplete process which must be supplemented by some other treatment such as kiln-drying or conditioning in a warm store. Nevertheless, within its limitations, it is a successful commercial process, which in spite of the steady growth of alternative methods, is always likely to have a considerable field of useful service.

In kiln-seasoning the essential factors of the process are under much greater control. Most types of modern kilns make ample provision for the maintenance of suitable temperatures and humidities. Arrangement is also invariably made for air circulation, the manner and degree of efficiency of which vary, however, in different types and designs. In some cases the air is moved mechanically by fans, while in others natural convection currents are relied on to give a circulation through the timber. Kilns may thus be divided into two classes, the fan and the natural draught types, on the basis of this difference. They may also be divided broadly into compartment or chamber, and progressive or tunnel kilns. In the first class the timber is placed in the kiln chamber where it remains stationary throughout the drying process. The air conditions are varied from time to time to suit the particular needs of the load. The kilns of the second group, as its name implies, take the form of a tunnel in which the timber entering at one end is moved progressively towards the other as the drying proceeds. It can be shown that the air conditions experienced by the timber at the different points of its journey through the tunnel kiln agree in a general way with those necessary to successful drying and with those which would be used in a compartment kiln for timber at corresponding stages in the progress of the drying.

It is not possible to include a more detailed description of the arrangement and uses of the various representative types of kilns in this present paper, and the interested reader is recommended to consult other publications[1] for information on these matters. It may be of interest, however, to consider kiln types briefly in a broad and comparative sense. In the fan kilns, the circulation through the layers of piled timber is generally quicker than in those of the natural draught type. It has already been explained how this will lead to a more uniform drying of the pile as a whole, and from this it follows that where the full kiln load is required to be dried uniformly to a given moisture content, as is mostly the case in practice, this result will be obtained more quickly when the air movement is faster. The fan kilns, therefore, give more rapid results for this reason and are preferable more particularly where green or easily dried timbers are concerned. Where the material to be seasoned is already partly dried, as is often the case with imported species, the fan kilns though still the quicker have less opportunity to exploit this advantage and the greater cheapness and simplicity of the natural draught type may compensate for its lack of speed. While both kinds of kiln may be used for all classes of work, the greatest efficiency of the natural draught type is found in the restricted field of drying partly seasoned and slow-drying timbers, but for all-round work a kiln with a forced air movement is preferable.

The above discussion should be considered as applying only to kilns of the compartment type, for in progressive kilns, which are most often though not always dependent for circulation on natural air movement, the same considerations do not apply. The progressive kilns form a distinctive class and have a special field of usefulness. For drying very large quantities of timber of one kind and one thickness, preferably where the thickness is not great, the initial moisture content is fairly uniform and not high and the boards are shorter than the width of the tunnel, the progressive kiln is an excellent dryer. It is economical, steady, and requires little attention. The output of dried timber is continuous and lends itself to the requirements of steady production. On the other hand, when the conditions favourable to steady working are not fulfilled, its efficiency falls off rapidly, and where small quantities of timber varying either in species, in dimensions, in moisture conditions, or in their seasoning qualities have to be dried, compartment kilns, in which each class of material can be dealt with separately according to its special needs, are to be preferred.

The cost of kiln-drying can be dealt with no more adequately than that of air-seasoning. The interest on the capital expenditure for the kilns and plant required, rent, rates, insurance, and depreciation must of course be considered. Steam for heating may necessitate a special boiler and become an important item in the cost of drying, especially where fuel has also to be bought, though in a large steam-driven factory sufficient steam may conceivably be available from existing boilers which are perhaps fed from waste products, so that its

[1] *Forest Products Research Special Report*, No. 2; 'The Kiln Drying of Lumber', by H. D. Tiemann; 'The Kiln Drying of Lumber', by Koehler and Thelen.

cost in this case may be almost negligible. The efficiency of the handling and piling of the timber also influences the cost, not only by cheapening the charge for labour, but by allowing of a more continuous use of the drying plant. A further charge might be added for supervision and operation of the plant. It is well to state, however, that this item must not be considered alone, for the degree of success in kiln-drying is largely personal to the operator, whose cost should be regarded therefore in relation to results. It is certain that the man with the lowest pay will rarely prove the cheapest.

Kiln-seasoning has many indirect economic advantages. Timber can be kiln-seasoned to an exact requirement of moisture content and this is an important matter in the manufacture of furniture, flooring, panelling, and many other products. Small storage space is required to hold the relatively light stocks which it is necessary to carry, and full use can be made of market conditions. For this reason kiln-drying is almost an essential to a high rate of production. If necessary, too, kilns afford the quickest and surest means of killing fungus or insect in decaying or infested timber.

It should perhaps be added that with equal care and skill, kiln-seasoning will give results equal to and even better than those obtained from air-seasoning, and it is likely that the process, which has grown considerably during recent years, will continue to make still greater progress as its many advantages become more widely appreciated.

It would be inappropriate to conclude solely on this note. Technically, kiln-drying is undoubtedly a superior method and but for its frequent economic advantages air-seasoning would have little place. In a practical world, however, the questions of expediency and cost play the all-important part, and it is for this reason that brief notes concerning the economic aspect of the two processes have been included in a paper which is otherwise mainly technical in character. Finally, it must not be overlooked that the processes can be combined as a preliminary air-drying followed by kiln treatment. It is possible to conceive many cases in which this arrangement would prove advantageous and in fact afford the best practical solution of the drying problem.

THE USE OF THE PROJECTION APPARATUS IN ANATOMICAL STUDIES OF TIMBERS

BY S. H. CLARKE

Forest Products Research Laboratory

IN the course of an investigation of the relationship between vessel size and the liability of various woods to attack by *Lyctus* (1), and also in the critical survey of the structure of elm wood (2), it was necessary to determine the dimensions of many thousands of wood elements. The ordinary methods of measurement under the microscope, involving the superimposition of two images, were found to be very slow and laborious, and frequently not so accurate as could be desired. In many cases the task was simplified by the use of a projection apparatus. The idea of measuring a projected image is by no means original, but there does not appear to be a record of the use of any methods as simple as those described below, one of which has been mentioned in a previous paper (1), though not so fully described, while the other is believed to be new.

Two kinds of projection apparatus were used. In order to obtain a low magnification (20 to 100 diameters) of a large area of a transverse section, a Leitz Small Micro Projector was used; this was clamped in a vertical position at a suitable height, so that the image was projected downwards on to a horizontal screen. Higher magnifications of 100 to 1,000 diameters were obtained by means of a microscope and a right-angled projection prism, and a screen essentially similar to that figured by Kribs (3).

Measurements of three kinds were made: firstly the actual dimensions of the wood elements, secondly the proportions in which they were present, and thirdly the number of elements present in a given area.

THE DIMENSIONS OF ELEMENTS.

The ordinary method of measuring the dimensions of elements (e.g. the diameters of a vessel as seen in transverse section) is to use a calibrated scale in the eyepiece of the microscope. The slide is moved on the stage of the microscope until one wall of a vessel coincides with a division of the eyepiece scale, and then the diameter of the vessel is measured in divisions of the scale. Then either the slide or the scale is turned through 90°, and the other diameter measured. The numbers obtained are multiplied by a constant to convert them to metric units. Greater accuracy can be obtained by using a special eyepiece, containing two hair-lines, one of which is fixed, while the other may be moved through a known distance by means of a thumb-screw. The difficulties presented by this method are chiefly those encountered in alining the images of the section and the scale. Without a mechanical stage this is a tiresome operation; if the movable hair-line type of eyepiece is used, a mechanical stage is a

disadvantage unless the stage also rotates. With even the finest lines it is usually difficult to be quite certain of the alinement, and considerable error may be introduced in the measurement of small distances. Moreover, it is necessary to move the slide very carefully every time a vessel is measured.

The first question that arises in connexion with the projection method is the magnification to be used. In measuring the diameters of vessels a magnification

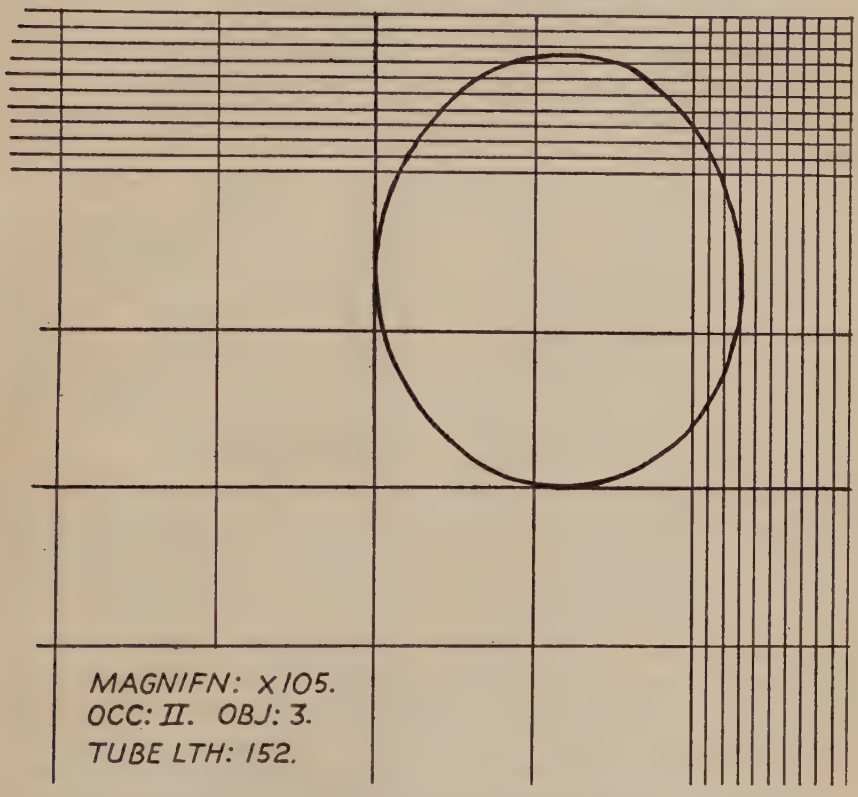


FIG. 1. Typical scale, showing method of measuring the dimensions of a vessel.

of 100 to over 700 diameters may be required; for the lengths of tracheids or fibres, a magnification of 30 to 50 diameters is usually sufficient. A convenient magnification having been chosen, a scale is prepared by projecting a millimetre scale, and tracing it on a piece of Bristol board. A typical scale is shown in Fig. 1. The conditions for obtaining the magnification should be plainly written on the scale, and checked each time the scale is used, if any changes in the adjustment of the microscope have been made in the meantime. The large divisions on the scale represent 100 μ, and the small ones 10 μ. The image of the transverse section of the wood is then projected on to the screen. There may be ten or more vessels in the field and these can all be measured without moving the slide. The scale is moved over the screen so that each vessel in turn

takes up the position shown in Fig. 1. The radial and tangential diameters can then be read directly to the nearest 5μ. The dimensions of the vessel in Fig. 1 would be 275 and 232μ. Alining the scale is much less tiring and more accurate than moving the slide as described above. The recording of measurements is not easy in the screened area, and in practice it is found that the time taken is less than a third if the dimensions are dictated to an assistant. With practice four to five thousand vessels can be measured in one day. The average mean diameter of 100 spring wood vessels of a sample of *Ulmus major* was found in five successive measurings to be 311·0, 311·2, 312·9, 312·9, and 311·3μ. The differences are due in part to the fact that sometimes it is difficult to decide whether a vessel belongs to the spring or the summer wood, and it may be counted at one time and not the next.

THE PROPORTIONS IN WHICH ELEMENTS ARE PRESENT.

In determining the ray volumes of certain woods, Myer (4) prepared photomicrographs on bromide paper at a magnification of 100, cut out the rays, and found the ratio of the weight of the rays to the weight of the whole photograph. This method was applied to the structural investigation of elm in determining the proportion of fibres present in different samples, but was replaced by the method to be described for two reasons. In the first place it was only applicable to small samples of wood, and in the second place the preparation of stencils was found to be very slow and expensive.

A Shand's Recording Micrometer was used with good results, and finally the instrument illustrated in Fig. 2 was designed to apply the idea of the Recording Micrometer to a projected image. The transverse section under examination is considered as an infinite number of parallel strips each of infinitely small width. If the proportion in which any type of element is present is measured in a sufficiently large number of strips a figure giving the proportion in which the element is present in the wood as a whole can be obtained. The instrument shown in Fig. 2 consists essentially of a pointer which is moved along a straight line by means of two independent thumb-screws, any movement of the pointer caused by screw A being recorded on the scale a, and by the screw B on scale b. In determining the proportion of fibres present in a sample, the instrument is placed on the screen, and the pointer moved by screw A as it passes over a group of fibres, and by B as it passes over other elements. Suppose the final readings to be a and b, then $100\,\frac{a}{a+b}$ represents the percentage of fibres present in the sample. Successive results for the same line were 54·9, 54·9, 55·0, 55·0, and 55·3 per cent. In another case one observer obtained as successive results 42·5, 41·8, 42·6, 42·3, 42·4 per cent., and a second observer then obtained a result of 42·6 per cent. Successive measurements along parallel lines in a single sample gave the percentage of fibres present as 55·0, 55·75, 52·6, 56·0, and 56·1. The average of these figures is sufficiently accurate for comparative purposes. The actual number of determinations necessary for each sample is variable, and depends upon the problem in hand. The apparatus is equally efficient in deal-

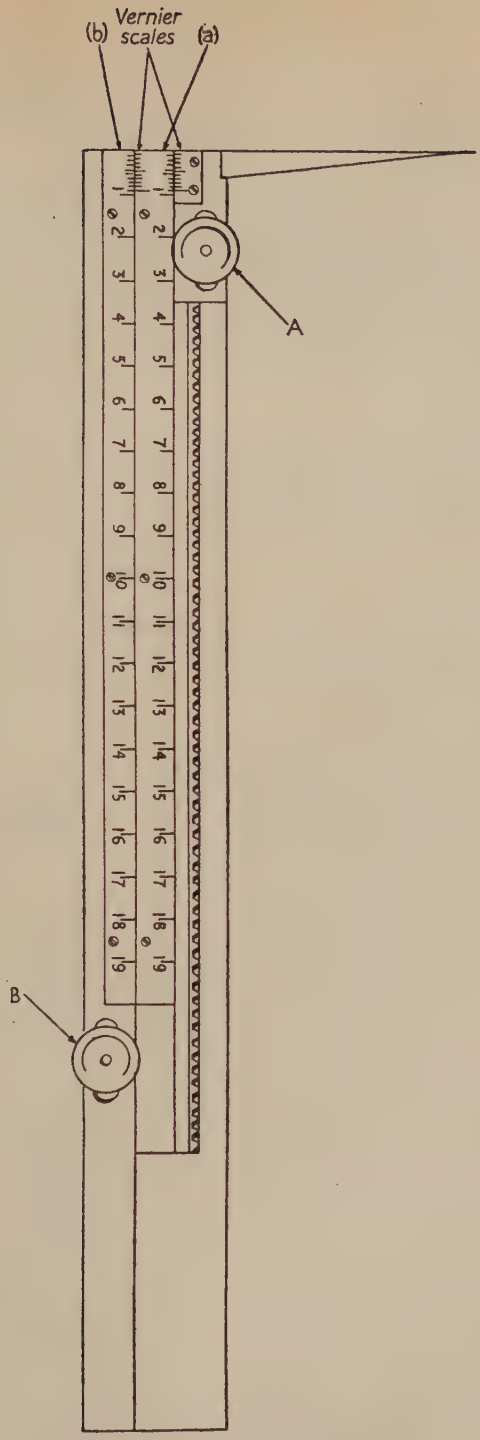


FIG. 2. For description see text.

ing with large areas of a section at a low magnification, or with small areas at a high magnification. Where a large area is needed at a high magnification, a Shand's Recording Micrometer is more suitable.

THE NUMBER OF ELEMENTS PRESENT IN A GIVEN AREA.

A further use for the projection apparatus is found in counting the number of rays or vessels in a given field. A convenient method is to mark out on a piece of paper a plot to represent the required size (say 1 sq. mm.) and paint the outside of the area black. This paper is placed on the screen and covered with a sheet of glass, and the counting is then done by dotting the elements in question with pen and ink.

ACKNOWLEDGEMENTS.

I wish to express my thanks to Mr. R. S. Pearson, C.I.E., F.L.S., Director of Forest Products Research, for permission to publish this account, and to my colleagues of this Laboratory for much help in the development of the ideas recorded.

SUMMARY.

Descriptions are given of simple methods of making anatomical measurements by using a projected image. The methods described enable direct readings to be made of:

(*a*) the dimensions of elements,

(*b*) the proportions in which elements are present,

(*c*) the number of elements in a given area.

An instrument designed to determine the proportion of fibres, or other elements, in a sample of wood is described and illustrated.

REFERENCES

(1) Clarke, S. H.: 'On the relationship between vessel size and *Lyctus* attack in timber.' *Forestry*, 1928, ii (2), pp. 47–52.

(2) Clarke, S. H.: 'The anatomical structure of home-grown timbers and the relation of structure to strength.' *Forest Products Research Laboratory*, *Project* 18, *Progress Report I. Elm.* (In the press.)

(3) Kribs, D. A.: 'Length of tracheids in jack pine in relation to their position in the vertical and horizontal axes of the tree.' *University of Minnesota Agric. Experimental Station. Tech. Bull.* 54. 1928.

(4) Myer, J. E.: 'Ray volumes of the commercial woods of the United States, and their significance.' (*Am.*) *Journ. For.*, 1922, xx, pp. 337–51.

PRODUCTION OF HARDWOODS

(Communicated by the Forestry Commissioners)

COMPOSITION OF BRITISH WOODLANDS.

1. The Census of Woodlands 1924[1] showed that the areas under different types of forest in Great Britain were, to the nearest 1,000 acres, as follows:

	Acres.	*Acres.*
Conifers	672,000	
Hardwoods	443,000	
Mixed hardwoods and conifers	302,000	
Total High Forest		1,417,000
Coppice and coppice with standards		529,000
Total Economic Woodlands		1,946,000
Amenity, shelter belts, &c.		204,000
		2,150,000
Scrub, felled or devastated		809,000
Total		2,959,000

2. The production of hardwood saw-timber is mainly from the woodlands classified above as 'hardwoods'. 'Mixed hardwoods and conifers', 'coppice with standards' and 'amenity', as well as hedgerows (not included in para. 1), also contribute to the supply. The total amount felled or sold for felling in 1924 was 14·6 million cubic feet, valued at £923,000 standing, 11·8 million cubic feet being in England, 1·3 million cubic feet in Wales, and 1·5 million cubic feet in Scotland. A rough analysis of the data from which the Census of Production figures were derived indicates that of the total volume 50 per cent. was obtained from the hardwood areas, 12 per cent. from the 'mixed', 27 per cent. from the coppice with standards and amenity woods, and 11 per cent. from hedgerows.

Further, of the total volume 80 per cent. came from England and 10 per cent. each from Scotland and from Wales.

3. In considering the maintenance of the home-grown hardwood supply it seems unlikely that any appreciable part of the woodland area at present under conifers will be planted with broad-leaved species. The future therefore is bound up with the treatment of the categories of woodland mentioned in paragraph 2 and with the possibility of afforesting land at present bare.

THE FUTURE OF WOODLANDS NOW PRODUCING HARDWOOD TIMBER.

4. Viewed as an economic forestry problem continuity in supply of hard-

[1] Forestry Commission: *Report on Census of Woodlands and Census of Production of Home-grown Timber*, 1924, published by H.M. Stationery Office. Certain aspects of this and kindred questions are there discussed in greater detail.

woods from the existing woodlands rests mainly with the existing 'hardwood' areas. 'Mixed hardwoods and conifers' is not a good method of growing hardwoods unless the conifers are removed in good time leaving the hardwoods to form the final crop, in which case the area automatically becomes 'hardwood'. Frequently the necessary thinnings are not made in time, the hardwoods do not develop satisfactorily, and the final value of the crop lies mainly in its softwood contents. The growing of standards in coppice was at one time very well managed in England, but for various reasons the system has become almost obsolete, so that standards are not now 'stored' on anything approaching the former scale. Amenity woods, shelter belts, &c., are definitely classed as uneconomic woodlands because primarily they serve other ends than timber production.

5. If the age classes of the existing woodlands are examined it will be found that there has been a remarkable decrease in the planting of hardwoods over the last century or so. The figures in the table below illustrate the point, and though the decade 1915–24 was of course quite abnormal it is clear that the tendency, so far as it applies to private woods, has not been reversed.

Average Area planted annually.

	1845–84	1885–1904	1905–14	1915–24
	acres	acres	acres	acres
Hardwoods	4,500	2,000	1,000	500
Mixed hardwoods and conifers .	3,400	3,200	1,600	1,100
	7,900	5,200	2,600	1,600

The reasons why hardwood and mixed plantations have fallen into disfavour are numerous, but broadly the change is an expression of changing economic conditions. During the earlier decades of the nineteenth century, oak for shipbuilding was an important consideration. Much land (and incidentally a fair proportion unsuitable for the purpose) was planted with that species, pure or with coniferous nurses, and subsequently thinned very heavily to produce the branched trees suitable for boat-building. As this market receded and the national demand for softwoods increased woodland owners gradually restricted their plantings of hardwoods. There are also other important reasons why conifers were preferred to hardwoods. The latter, and oak in particular, require better soil than conifers, the age of maturity is frequently twice as great, the expense of forming the plantation is greater as is also the cost of protecting it in the early stages against weeds, the thinnings are longer delayed and often of smaller value: thus all the inducements to the private owner were (and continue to be) to plant conifers rather than hardwoods.

6. When all the facts stated above are taken into consideration the conclusion is irresistible that the area of privately owned woodlands producing hardwood timbers will continue to diminish and the out-turn must also diminish.

To maintain the existing area of 'hardwoods' alone (443,000 acres) on a rotation of 150 years it would be necessary to plant or otherwise regenerate 3,000 acres annually. The danger of serious diminution in out-turn is not immediate since there are some 208,000 acres of hardwoods over 80 years old. Indeed the out-turn may increase considerably if woodland owners are forced for any reason to realize on the value of their woods. A lean time will begin when the woods now over 80 years old are cut and a leaner still when the woods now 41 to 80 years (180,000 acres) are gone.

THE POSSIBILITY OF INCREASING THE HARDWOOD AREA BY AFFORESTATION.

7. Bearing in mind the fact that hardwoods require good soil it will be realized that the possibilities in this direction are distinctly limited. The proportion of suitable land found in the uncultivated land available for afforestation is very small. In the case of mountain and heath land it is usually restricted to quite small patches.

Another source of supply is in the marginal agricultural lands and especially the heavier soils. It is at least doubtful whether wholesale afforestation would be to the general national advantage.

POSSIBILITY OF INCREASING PRODUCTION PER ACRE.

8. So far consideration has been paid only to the hardwood *area* without reference to the volume of timber produced per acre. It is a fact that British hardwood areas are poorly stocked and the trees short-boled and defective compared with good French and German forests. Mature oak woodlands containing more than 1,200 to 1,500 cubic feet of saw timber per acre are rare, whereas with improved methods of silviculture the soil might be made to produce at least double these quantities in the same time.

THE FORESTRY COMMISSIONERS' POLICY.

9. In considering the question of softwood versus hardwood planting the following considerations must be borne in mind. At the present stage of the world's industrial development the overwhelming demand is for softwoods. So far as Great Britain is concerned only some 10 per cent. of the current consumption is hardwoods. Similarly in the war the bulk of the fellings took place not in the hardwoods, which remained reasonably intact, but in the coniferous plantations both old and immature. It is necessary also to envisage the probable timber supply position at somewhat distant periods. In a general way it seems certain that the world competition for timber will be far greater in the future as regards softwoods than as regards hardwoods. The softwood position has been discussed very fully in Parliament and in the technical press from time to time and it is unnecessary now to go into it in detail. The hardwood position may conceivably become acute in the distant future, but before real hardship is incurred many valuable tropical species will have to be worked out.

10. The general policy adopted by the Commissioners has been to replace as

quickly as possible the coniferous plantations which disappeared as a result of the war. Consequently their plantations have, so far, been made mainly with conifers and must continue so to be if the deficit is to be made good. The hardwood question, however, has not been neglected. The steps which are being taken are described below.

11. The former Crown Woods, amounting to some 60,000 acres, are being regenerated so far as practicable to hardwoods (oak, beech, ash, and sycamore). A proportion only of the soil is suitable for oak and less still for ash, which is a very exacting species. Preference is given to those two species and then in descending order to beech, sycamore, and finally to conifers. A considerable area of oak is being regenerated naturally, and with success, with that species and is not included in the areas returned as planted.

12. From time to time land is acquired which has carried a crop of hardwoods. As a rule such land is difficult and costly to deal with. The lop-and-top has not been cleared up, weed and coppice growth has become very rank, and an important consideration is to get the area covered as quickly as possible with a quick-growing species. Thus part only is planted in the first instance with hardwoods and the remainder with conifers which serve as a cleaning and catch crop.

13. Suitable areas of bare land have also been acquired and planted or sown with hardwoods. This is a somewhat difficult operation as hardwoods require nursing in youth and any attempt to force the pace in planting only results in high losses of plants.

14. As a general rule hardwood plantations are much more difficult than conifers to establish. Not only is more skill required but far greater patience has also to be exercised. A great deal of experimental work has been carried out and results have been obtained or are in sight which should gradually enable the Commissioners to proceed in future with large-scale operations.

15. It has been urged that by paying a little more for land a considerably greater proportion of hardwood soil would be secured. Broadly, the statement is true, but it is also true that such action would result in the afforestation of land which more properly belongs to agriculture. The Commissioners have hitherto taken up the attitude that it is not in the national interest to do so.

16. More important than the afforestation of new land with hardwoods is the maintenance of the existing hardwood area which is mainly in private ownership and much of which is in small blocks and intimately associated with residential and agricultural properties. The problem of securing by State action the efficient management of private woodlands is in any event most difficult, and the possibility of restricting the user in the direction of hardwood production instead of more renumerative softwood production is even more remote. Short of compulsion the Commissioners have used the only means at their disposal by offering higher grants for planting hardwoods than for conifers. It cannot be said that the response has been satisfactory, nor is there any reason to believe that increasing the grants, within any reasonable limit, would have the desired effect.

SUMMARY.

17. The Commissioners consider that the most important problem immediately before them is to provide a supply of softwoods; at the same time they are not neglecting opportunities of acquiring suitable hardwood soils and concurrently they are attempting to improve methods of raising hardwood crops. The maintenance, indefinitely, of the supply of home-grown hardwoods on its present scale is unfortunately a problem to which at present they see no complete solution.

December 1929.

FORESTRY COMMISSION,
22 GROSVENOR GARDENS, S.W.

REVIEWS

Recent Research on the Microchemical Reactions of Woody Tissues.

A Note by B. J. Rendle.

IT is many years since the reliability of staining reactions in indicating the chemical constitution of plant tissues began to be questioned, and the diagnostic value of many of the botanist's standard reagents has now been sadly discredited. In actual practice botanical workers are not as a rule concerned with the chemical nature of their material so much as with the distinction between tissues which are associated with different physiological functions in the plant. The attitude of chemical investigators, on the other hand, is to regard the constituents of plant tissues as residues or extractives obtained after treating the tissues according to certain definite analytical methods. At present the views of chemists themselves on the constitution of the cell wall are so diverse that botanists are not in a position to form a considered opinion. The position is that in many cases they do not know the exact nature of the constituent affected by a particular stain or how the staining capacity of one constituent is affected by its association with another. In the meantime investigators in plant histology continue to use the stains with which they are familiar as a means of differentiating structures, and refrain from drawing conclusions on the exact chemical constitution of the different tissues.

In a recent series of papers Harlow (1–3) reviews the present state of our knowledge of this subject with special reference to wood. It appears to be definitely established that the middle lamella in unlignified tissues is of a pectic nature. The stain used for demonstrating the presence of pectin in these tissues (ruthenium red) also has a strong affinity for the middle lamella in lignified tissue, and in view of this observation the presence of pectin in wood was generally accepted as a fact. While the conclusions of the earlier work on parenchymatous tissues were supported by chemical evidence, the subsequent deduction that the middle lamella in woody tissues is of a similar chemical constitution was apparently based entirely on the evidence of staining reactions. In the absence of any evidence to the contrary, therefore, the result of Ritter's (6) work, showing that lignin, not pectin, is the principal constituent of the middle lamella in secondary xylem, must be accepted.

The phloroglucin test for lignified tissues has been in general use for many years and is commonly regarded as one of the more dependable indicators. Czapek found that the characteristic red coloration was due to traces of an aromatic aldehyde, which usually accompanies lignin, and subsequent investigations tend to show that this explanation is fundamentally correct. According to Harlow's observations, however, the phloroglucin test may give a negative reaction with the secondary walls of the fibres in certain hardwoods, elements which are generally regarded as being strongly lignified. It is reasonable to conclude that the aromatic constituent which is responsible for this colour reaction does not invariably accompany lignin.

An obvious step towards placing plant histology on a rational basis is to isolate the various constituents of the cell wall in a chemically pure condition and to study their staining reactions under controlled conditions. This method was adopted by Mehta (5), in an investigation which is referred to below, and later by Harlow. As described in the

last of Harlow's papers, the selective action of a number of stains was studied on cellulose and lignin prepared from wood by standard analytical methods. It was found that most of the stains coloured both cellulose and lignin, irrespective of their reported specific affinities for pectin, lignin, or cellulose. The same stains were then applied to sections of untreated wood under precisely similar conditions, with the interesting result that in no instance was the action of any stain specific for certain layers of the cell wall but in all cases the middle lamella stained deepest while the remaining layers of the wall showed a fainter coloration. These observations are sufficient to indicate the unreliability of single stains in the analysis of woody tissues and the same applies to the results of so-called counter staining or double staining, where the final effect depends so largely on the order in which the stains are applied and their manipulation. It is not suggested that these objections detract from the value of stains in differentiating structural details which would otherwise be invisible; but in the light of present information it would seem unwise to place reliance on stains in studying the microchemistry of tissues which have not first been investigated by other methods.

As no reference is made in Harlow's papers to an investigation on similar lines carried out by Mehta, it will be appropriate to consider it here. The various constituents of the cell wall were isolated in the purest possible condition and their staining capacities determined. It is again evident from these results that most of the stains are not at all specific as they stain a number of different constituents of the cell wall. For example, ruthenium red was found to stain, in addition to pectic substances and their derivatives, α-, β-, and γ-oxycelluloses, hemicelluloses, gums, galactans, lignin, mannan, and amylo-hemicellulose. As no specific microchemical colour reactions could be found for these substances, the method of extracting the different constituents by suitable chemical treatment was employed in investigating the microchemical constitution of the wood of *Pinus silvestris*. The principle of this method is to stain sections before and after treatment with a solvent for the constituent whose distribution is being studied. If a certain part of the cell wall reacts positively to a stain before treatment and negatively after treatment it is concluded that that part of the cell wall contained the constituent in question. Mehta's work on the wood of *Pinus silvestris* supports, in the main, the conclusions cited above, in that the middle lamella in young, incompletely lignified stems is found to consist of neutral pectic substance, while in mature wood it is composed of lignin, gums, and hemicelluloses, pectin being absent. This is in accordance with the consensus of opinion among wood chemists that pectin occupies a similar position in young tissues to that of lignin in mature wood. As yet no direct connexion has been traced between pectin and lignin, but a plausible explanation is that, in the course of lignification, the pectins are metamorphosed to form part of the lignin of the mature cell wall.

It is common practice in preparing samples of hardwood for microscopic examination to soften the material by treatment with hydrofluoric acid. Alcohol also is generally employed at some stage in the process. It is not unreasonable to suppose that these substances may affect the staining reactions of the tissues, and such treatment is naturally avoided as far as possible in critical work. It is of interest to note that Harlow found that, after treatment with hydrofluoric acid, wood sections failed to give the characteristic colour reactions to the phloroglucin and Mäule tests. More important, considering the common use of alcohol as a fixative and preserving medium, is Mehta's observation that sections extracted with alcohol give a negative reaction with phloroglucin and other stains.

REFERENCES

(1) Harlow, W. M.: 'The Chemical Nature of the Middle Lamella.' *Tech. Pub.* No. 21, New York State College of Forestry, Syracuse, New York, 1927.

(2) Harlow, W. M.: 'Lignification in the Secondary and Tertiary Layers of the Cell Walls of Wood.' *Tech. Pub.* No. 24, New York State College of Forestry, Syracuse, New York, 1928.

(3) Harlow, W. M.: 'The Reliability of Staining Reagents in Microchemical Studies of Plant Cell Walls' and 'Some Microchemical Reactions of Woody Tissues previously treated with Hydrofluoric Acid'. *Tech. Pub.* No. 26, New York State College of Forestry, Syracuse, New York, 1928.

(4) Mehta, M. M.: 'Biochemical and Histological Studies on Lignification. Part I. The Nature of Lignin: its Physiological Significance and its Estimation in Timbers.' *Biochem. Journal*, 1925, xix, 6, pp. 958–78.

(5) Mehta, M. M.: 'Biochemical and Histological Studies on Lignification. Part II. Histological Studies on the Polysaccharides and Aromatic Constituents of the Cell Wall.' *Biochem. Journal*, 1925, xix, 6, pp. 979–97.

(6) Ritter, G. J.: 'The Distribution of Lignin in Wood.' *Journ. Ind. Eng. Chem.*, 1925, xvii, 11, pp. 1194–7.

Recent Research in the Hastening of the Germination of Tree Seeds.

A note by H. M. Steven.

ONE of the principal subjects studied by the Boyce Thompson Institute for Plant Research, New York, has been the rest state in seeds and vegetative parts of plants, and means of shortening it. Three recent papers from that institute which deal with tree seeds deserve to be brought to the general attention of foresters.

The first by Crocker (3) is a report of an address read at a short course for nurserymen at the Ohio State University—our universities have yet to become so vocational! This paper deals with the harvesting, storage, and stratification of seeds in relation to nursery practice, and it contains two points of interest to foresters, namely, the use of peat as a medium in which to stratify seed, and a summary of work done on the storage of birch seed.

All three papers here reviewed deal principally with the role of stratification of tree seeds as a means of hastening germination, and the extensive equipment of this physiological laboratory has enabled methods of precision to be employed. This is not a new subject, for Zederbauer contrasted different types of stratification with other methods of seed storage, while more recently Tozawa has drawn attention to the use of this type of storage to hasten and increase the germination of certain Japanese species. Concerning peat as a stratification medium Crocker states: 'Of the several media (sand, muck, soil, and granulated peat) that we have tried, granulated peat, used extensively now by nurserymen, has proved the most satisfactory. Peat is superior to the other media because it can be pressed free enough from water to give a good air supply and at the same time contain enough water to prevent excessive drying for long periods. It holds more than ten times as much water as sand when both contain the best water content for stratification. . . . To get the best results from stratification there must be a proper regulation of water, and air; no part of the medium containing the seeds should be too dry or waterlogged. This condition can best be maintained by shifting the stratified

material from one box to another every three or four weeks, supplying water when needful and loosening up the mass where it is too compact to give good air supply.' This use of peat deserves a trial in this country.

The second subject, the stratification of birch seed, is of special interest to us in this country, because of the likelihood of the wider use of birches as nurse crops in afforestation. Those who raise birch plants know how variable results are, and if the data supplied for American species apply to European, then one cause of this is found and can be corrected. To quote again: 'Birch seeds stand in a class alone so far as our investigations go. When first harvested they germinate poorly at any temperature. When thoroughly air-dried for a month or more they will germinate only at relatively high temperatures (32° C. and alternation of 15° C. and 32° C. gave the highest germination while 15° C. gave no germination). If they are stratified at a low temperature they gradually fall in the temperature at which they will germinate until after five or six months of stratification they will germinate at the freezing-point. *Betula lenta* is extreme in this respect. The air-dried seeds require 90° F. for germination. With stratification at 32° or 40° F. they gradually germinate at lower and lower temperatures until after five or six months' stratification they will germinate at the stratification temperatures. Stratification in this case causes a fall of nearly 60° F. in the germination temperature.' For the American birches Crocker recommends an optimum stratification temperature of 41° F. with an effective range of 32 to 50° F. and a stratification period of 60 to 75 days. If this holds for the European species then the best practice will be to air-dry the seed after collection, and store it thus until January or February, then to stratify. During the period January to March the air temperature will generally be within the effective range.

The two papers by Barton (1 and 2) deal with the effect of stratification on coniferous species. The first paper deals with the Southern pines, *Pinus echinata*, *P. palustris*, *P. caribaea*, and *P. taeda*, and hence outside America will be of interest only to South African and Australasian foresters. The method of procedure in stratification consisted in mixing the seeds with moist acid peat enclosed in cheese-cloth bags, and putting these into the compartments of large partitioned aluminium trays. These were then placed in constant temperature ovens. The stratification temperatures used were 0°, 5°, 10°, and 15° C. and the periods 1, 2, 3, and 4 months. At the end of each period seed was planted in flats containing sand and wood soil, along with unstratified seed as a control. The temperature during germination was 69° F. or higher. The subsequent germination results showed a very striking hastening of germination by stratification in all species except *P. palustris* where the difference between treated seed and control was not so marked. In the case of the other species, almost complete germination was secured in 10 to 20 days when only a few of the control seeds had germinated. The latter gave a much lower final result, and then only after 100 days. For practical purposes stratification for 2 months (1 month for *P. palustris*) at 5° C. seemed desirable although the temperature of stratification had little apparent effect.

In Barton's second paper, the above methods were extended to a large number of other coniferous species. The following are some of the conclusions for species of interest to us in this country.

P. contorta. The response to stratification was definite and favourable. The optimum temperature for stratification seemed to be 5° C., and the time 2 months. Seeds planted after this treatment gave 86 per cent. germination in 18 days, whereas the average for the controls was 51 per cent. in 28 days.

P. contorta murrayana. Stratification at either 0° or 5° C. for 1, 2, or 3 months is decidedly beneficial in the production of prompt and complete stands of seedlings.

P. insignis. The 5° C. treatment for 2 or 3 months gave 75 to 84 per cent. germination in 14 to 18 days compared with 69 per cent. and 50 to 70 days for controls.

Picea excelsa. Stratification at 0° C. for 2 months was best, almost doubling the germination.

P. sitchensis. Less success was obtained with this species. Two months' stratification gave 24 per cent. after 27 days compared with 4 per cent. after 40 days. Nursery technique is specially important in this species as has been shown by the reviewer in *Forestry Commission Bulletin* No. 11.

Taxodium distichum. A notable increase in germination was obtained by stratification at 5° C. for 1 month.

There are only two criticisms to be made of this work. Firstly, the number of seeds used for each test was very low, and there were no adequate replications, and secondly check sowings under nursery conditions should have been made. In a study of this kind, the first at least is essential. Nevertheless, the results are very interesting, and this method of cool stratification in peat deserves a careful and extended trial for our species, with sowings under normal nursery conditions.

REFERENCES

(1) Barton, L. V: *Hastening the Germination of Southern Pine Seeds.* Boyce Thompson Institute for Plant Research, Professional Paper No. 9. October 1928.

(2) Barton, L. V.: *Hastening the Germination of some Coniferous Seeds.* Contributions from the Boyce Thompson Institute for Plant Research, Inc. Vol. ii, No. 5, p. 315, February 1930.

(3) Crocker, W.: *Harvesting, Storage and Stratification of Seeds in relation to Nursery Practice.* Boyce Thompson Institute for Plant Research, Professional Paper No. 15.

The Economics of Forestry, by W. E. Hiley, M.A. Clarendon Press, Oxford, pp. xiv + 256. 21*s.*

Review by Professor Henry Clay.

MR. HILEY'S book is a contribution to economics of a type that is rare in this country, though not uncommon in America. It is an economic, not a technical study; but it could have been done only by an economist with a detailed technical knowledge of the technical conditions of the industry. The principles of general economic theory are thus made to illuminate the problems of forestry; while the technical peculiarities of that industry illustrate the limits and true meaning of those principles.

The object of forestry, as of any other industry, is to yield a surplus of receipts over costs. Receipts depend on price and yield, on the former of which at any rate economics has something to say. Costs in their turn are susceptible of an analysis that has much in common with other industries. The distinctive feature of forestry, that explains most of the difficulties of accounting in it, is that the return is a deferred return, and the balancing of costs and receipts has to be done over a longer period than in the case of any other economic enterprise, except perhaps the greater public works. In any attempt to ascertain the results of a business, the valuation of work in progress constitutes a problem; in forestry, when work may be in progress for a century before it becomes marketable, everything turns on this valuation.

After a survey of existing and potential supplies of timber, and of consumption and

demand, Mr. Hiley attacks the question of price. Since forestry means present expense for a distant return, its economic results depend not only on the relation of costs to prices now, but on the trend of prices in the future. A distinction has to be drawn between the influences that affect the price of timber, as distinct from other things, and the influences that determine the general level of prices or purchasing power of money. A useful summary of economic theory on both aspects of price determination is given.

In the second and longer part of the book, the subject of the profitableness of forestry is studied, and methods collected and devised of measuring, checking, and controlling costs and results. The chief insistance is on the necessity of making proper allowance for interest charges. Different methods are analysed: the most useful is the calculation of the financial yield, or return on the capital invested, and a method of calculating this is given. The different methods are illustrated and tested by the use of actual statistics of timber yield and financial results, which bring out the interesting result that the calculation of financial yield also establishes the optimum financial rotation for any species of tree. An important result of these calculations is to indicate gaps in technical knowledge to which research should be directed, if forestry is to be enabled to operate profitably.

The chief value of the book will be to the forester, to whom it will be indispensable. It provides him with a technique of accounting which will enable him to base his policy on precise estimates of financial results instead of guess work. It brings together such formulae as there is at present any chance of using, and a great deal of material on yields, &c., that makes it possible to give values to the terms in the formulae. It has a value also to the general student of economic problems. By substituting precise calculations for vague assumptions, it makes possible an estimate of the profitableness of systematic forestry. There is a tendency to assume that, because the return is distant and the costs are borne by public authorities, it is unnecessary to bother about the relation of return to costs. Mr. Hiley's calculations will surprise many political advocates of afforestation schemes; they are particularly valuable in demonstrating the fallacy of aiming at maximum *gross* income from a plantation instead of maximum *net* income, and in showing the economy of using better rather than inferior soils. If no allowance is made for the possibility that timber prices will rise, the returns shown are so low that they hardly in themselves justify a large investment. Mr. Hiley refers to and admits the incidental advantages that forestry confers; the one addition to this treatment of the subject that suggests itself is an elaboration of these, and an attempt to assess their economic importance.

Loch Ossian Plantations. An Essay on Afforesting high Moorland, by J. S. M. Privately printed, 1929.

Review by the Editor.

THIS little book by Sir John Stirling-Maxwell is an important contribution to forestry knowledge, and, what is more, is fascinating to read because of the wealth of local colour and acute observations.

Particularly in Scotland, the great extent of peat-covered land, at present of little use, and located in regions which are very sparsely populated, is at once a challenge and a lure to an industry such as forestry which has to deal with land not already intensively utilized. It can be said without exaggeration that sober forestry judgement would have advised against following this will-o'-the-wisp into the bogs, had it not been for the

pioneer and in many respects encouraging work which Sir John Stirling-Maxwell has carried out during the last thirty years at Courour.

The general conditions and object of the work can best be conveyed by quoting from the Introductory Note: 'These plantations, intended to improve the landscape and afford shelter for the deer, were begun without much consideration. They all lie above the 1,250 feet contour. The soil is for the most part poor and covered with peat. The first trees were planted in 1892 and the first regular enclosure was made the following year. The earlier planting was restricted to such parts of the ground enclosed as were not supposed to require draining. The result, though very far from successful, had a certain interest in view of the increasing belief in afforestation. Since 1925 a number of experiments have been made—largely based on similar work in Belgium—in order to find out whether it is possible to convert poor moorland soil into forest at this altitude in Scotland. In recent years the main object has been the conversion of the pine plantations into spruce.'

Only some of major achievements and results can be referred to here:

1. The failure of Scots pine as a timber tree. Cold summers, wet winters, strong winds, snow damage, insect pests, and fungal diseases all levied a heavy toll.
2. The success and promise of Sitka spruce. In this connexion it is interesting to note that trees raised from Alaskan seed have done best.
3. The demonstration of the great importance of drainage on such soils.
4. The introduction and demonstration of the advantages of the so-called Belgian system of draining and turfing. Had it not been for the author it is unlikely that this system would have been introduced into this country, and this system or modifications of it is the greatest hope of afforesting peat types generally.
5. Success in the use of basic slag.

There are two maps, and naturalists will be interested in the list giving the avifauna of Courour Forest.

Waldbau auf Ökologischer Grundlage, by Alfred Dengler. Julius Springer, Berlin, 1930, 39 m.

Review by the Editor.

THE importance of the forest industry in Germany is well illustrated by the continuous stream of major books on forestry subjects. This book by the Professor of Forestry at Eberswalde is the most recent work on silviculture.

The book is divided into two parts: the ecology of woods as a basis for silviculture, and the technique of silviculture.

In the opening section of Part I the forest is considered as a vegetation type. The relationship between forest and other ecological associations is considered and a general description given of forest types from tropical to polar and alpine conditions. This undoubtedly gives a setting for the consideration of German types which enables a proper perspective to be secured. A useful feature of this section is the provision of a map giving the major ecological formations of the world and a set of maps showing the distribution of the principal European forest trees. Following this is a brief discussion of climatic and edaphic factors in relation to tree growth. This section although compressed gives most of the recent work carried out in German and German-speaking countries. For example, the importance of soil acidity is more fully dealt with than in any other text-book of this kind which we know. Schmidt's work on the influence of soil reaction on the germination and early growth of pine and spruce is dealt with, showing

the adverse effect of alkaline and very acid media, and Olsen's and Hartmann's work on the pH range of a number of common herbage plants described. The extraordinary range from alkaline to very acid conditions which *Hypnum shroeberi* endures is interesting in view of the occurrence of this moss on many afforestation sites. It is useful to have this work readily available, although criticisms can be directed against some of the technique employed. Part I closes with a brief outline of the physiological life-history of woods.

Part II on silvicultural technique covers the usual field. There are fairly extensive notes on the silvicultural qualities of most of the indigenous and introduced forest trees, and sections on methods of working the soil, sowing and planting, thinning, and silvicultural systems. The space devoted to artificial regeneration is naturally limited, and this detracts from its value for this country. The section on thinning, although an improvement on most existing books, is still rather inadequate in treatment.

The principal criticism is that it is now inadvisable to endeavour to cover such a wide field in one text-book even when it runs to over 500 pages and costs almost £2. The different fields of silviculture are now so highly specialized that it is an anachronism to attempt it. The absence of any reference to work in any language but German is, of course, to be expected.

There are many illustrations which are reasonably well reproduced and the paper and binding are good. The book can be recommended as an up-to-date and workmanlike guide to German silviculture.

Australian Rain-Forest Trees, excluding the Species confined to the Tropics. By W. D. Francis, Assistant Botanist, Department of Agriculture and Stock, Brisbane. Pp. 348, with 213 full-page half-tone illustrations, 25 text-figures, and rainfall map. Obtainable from the Council for Scientific and Industrial Research, 314 Albert Street, East Melbourne, C.2. Price 10*s.* plus 5*d.* per copy postage.

Review by W. Dallimore.

THE author of this book over a period of many years has made a special study of the subject from the point of view of a trained botanist. It appears at an opportune time, a time when people who are trying to find openings for marketing Empire timbers are urging the necessity for forest officers obtaining a better working knowledge of the species of trees with which they have to deal, in order to help in the prevention of costly mistakes that are only too often made by shippers and others in sending home wrongly named and mixed woods. Now that the Forest Products Research Laboratory authorities are undertaking serious and prolonged tests with various Empire timbers, it is absolutely essential, not only that timbers for testing should be true to name, but that timber of the same kind and quality should be relied upon for future delivery; and forest officers are expected to further this desirable end. A work such as the one under notice is exactly the kind of book to help forest officers in acquiring the necessary knowledge of the trees amongst which they work, and it might well be taken as a standard for descriptive works on forest trees in other parts of the Empire.

The author begins by discussing the quality and general distribution of rain forests in Australia, with a rainfall map of eastern Australia, and short descriptions of such essential subjects as rain-forests in relationship to soils and soil-forming rocks, the effects of bush fires, peculiarities of rain-forest trees, i.e. buttresses, character of bark, &c.,

the whole being well illustrated. Then comes the systematic part of the work, which is begun by brief descriptions of the Families, followed by an artificial subdivision of Australian rain-forest into groups to facilitate identification. This is followed by descriptions of species under the botanical name, with synonyms when necessary, and various common names. The descriptions are in every way excellent, for they are to the point and in easily understood language, the use of technical terms being avoided wherever possible. The description is followed by details of distribution, uses of the timber, &c., and a reference to the original description of the species and other references of interest. Many of the species described are illustrated by full-page photographs of mature trees and by drawings of shoot, leaves, flowers, and fruits. In some cases there are also photo-micrographs of the wood. The book runs to 347 pages including a good index. Although the type is rather small the printing is good, whilst the reproduction of drawings and photographs is excellent. The worst part about the book is the binding which is not worthy of the work: however, better could not be expected at the price of 10*s.* plus postage 5*d.* per copy. The book is published under the auspices of the Council for Scientific and Industrial Research, Commonwealth of Australia.

Principles of Forest Entomology, by S. A. Graham. McGraw-Hill Book Co. Inc. New York. 1929.

Review by J. W. Munro.

DURING the past fifteen years a change of outlook has taken place in American forest entomology, as can readily be seen in a study of the literature from the time of Packard to the present day.

The change is a transfer of interest from somewhat academic and toxonomic work, notably on the bark-beetles, to the study of the actual conditions prevailing in the American forests. Professor Graham's book well illustrates the modern trend of forest entomology in America. From the introductory chapter to the final one the American ecological outlook as fostered by Chapman, Craighead, and Graham himself is everywhere evident.

In an introductory chapter Professor Graham discusses the extent of the losses caused to American forestry by insects and lays stress on the importance of forest entomology. Then he defines the scope of forest entomology which in the United States is at present mainly in taxonomic and ecological work. One important point he makes is that while there is need for morphological, histological, and physiological work it is much to be hoped that with so many branches of entomology in which to work the forest entomologist may not become too specialized, or too absorbed in any one of them. There is no doubt as to Professor Graham's position: he is definitely and unashamedly a forest entomologist who has already done good work in helping to elucidate the principles which underlie the control of the insects injurious to felled timber and of such insects as the spruce bud-worm and the white pine weevil.

In an historical chapter Professor Graham describes the gradual development of the ecological outlook in American forest entomology, a development which is, as we have said, relatively recent and to which he himself has contributed. His historical account of European forest entomology is good so far as it goes, but surely Karl Eckstein of Eberwalde, Cholodkovsky, Börner, and Marchal deserve honourable mention. By an oversight a portrait referred to on page 20 as that of Nitsche (Fig. 11) is that of Dr. J. M. Swaine. None of the portraits of European entomologists given are good, and Dr. Graham might have done better had he asked these entomologists themselves to supply

their portraits. I write with feeling, for I am one of the victims of Professor Chapman's camera which is responsible for the offending portraits published.

Chapters III and IV are devoted to a discussion of 'Biotic potential' and 'Environmental Resistance', terms which we owe to Professor Chapman and which may be, as Professor Graham describes them, apt but which, in my opinion, tend to disguise the complexity of the struggle for existence to which they are applied. Terms such as these and Hopkin's Bioclimatic Law and Host Selection Principle are misleading, because to the young student they suggest that the ideas underlying them are new, and because such terms as 'Law' and 'Principle' ought not to be used to describe hypotheses which are far from being fully tested.

These chapters, which are somewhat elementary, are doubtless intended to be so, but that a discussion is intended to be of a simple nature is no reason why it should be carelessly written. To describe climate as 'the result of the combined action of all the physical factors of the environment over a long period of time' may or may not be helpful, but to say that 'it (climate) forms the basis of Hopkin's bioclimatic law' is nonsense. So, too, when Professor Graham writes: 'Thus the black spruce is able to reduce budworm abundance' (p. 50), when he means that a high proportion of black spruce in a mixed forest is unfavourable to the increase in numbers of the budworm, he is guilty of loose thinking and careless writing. Such loose thinking and careless writing occurs throughout the book and detracts from its value. This is the more to be regretted because Dr. Graham has, as we know from his published papers, knowledge to convey which is both sound and useful. His chapters on the control of forest insects by mechanical and chemical means are ordinary, but those on indirect control are well worthy of serious consideration both by foresters and entomologists. Chapters X to XV deal with various American forest insects classified according to their habitat and the nature of the injuries they inflict. To the student beginning field work they should prove very useful in enabling him to recognize these insects by their work. In his chapter on leaf-eating insects Professor Graham might have mentioned Hering's work on the leaf-miners, for although dealing with a group of insects which may be less injurious than the wholesale defoliators, it is of fundamental importance as a serious contribution to our knowledge of the physiology of leaf-eating insects.

The closing chapters (XVI and XVII) of the book deal in an elementary way with the parasitic and predacious enemies of insects.

It is always a difficult matter to assess the full value of books dealing with economic entomology. If they are to appeal to the beginner and to the practical man, who from the strictly entomological point of view is also a beginner, such books must be elementary, and for this reason it is almost invariably the case that books on economic entomology are disappointing to the entomologist. It is an easier and more gratifying task to write interestingly on pure entomology than to write on insect control. In the first case one can deal with all the minutiae of the subject which are interesting of themselves, in the second these minutiae are interesting only in so far as they have an immediate bearing on insect control. In working towards the control of an insect pest the economic entomologist touches on all the various branches of pure entomology, morphology, taxonomy, biology, and, it may be, on histology and physiology too, but he can rarely go deeply into them and must, if he is honest, be content to see many a fascinating problem awaiting solution which he cannot wait to solve, and, when he comes to write up his work, be content to accept the harsh verdict of the workers in pure entomology that his work is elementary or even uninteresting. In forest entomology one may spend ten years in careful biological work the results of which, in so far as they strictly relate to control,

can be dealt with in as many pages. There is no appeal against that injustice and the forest entomologist must be content to bear it.

So too, with Professor Graham's book, to the worker in pure entomology it may prove disappointing and elementary. Elementary it is. Are not principles by their very nature elementary? To those of us, however, who have practised forest entomology this book is doubly welcome. It records a definite advance in the outlook on forest entomology, and it is sincere. To me it recalls spruce bud-worm sample plots at Tabusintack in New Brunswick and long days in the forest discussing with Graham and Swaine the urgent need for ecological work in forest entomology. Professor Graham has demonstrated and expressed that need in his book, and for that reason, if for no other, it deserves a prominent place on the shelves of the forester's library.

The Plant Rusts (*Uredinales*), by Joseph C. Arthur and others. v+446 pages, with illustrations. Price 32*s*. 6*d*. New York, John Wiley & Sons, Inc. London: Chapman & Hall, Ltd. 1929.

Review by W. R. Day.

In this book an attempt has been made to give a complete and detailed general account of the rust fungi. The great biological interest and economic importance of these parasites has caused them to be the subject of study by a very great number of investigators, and the literature which has accumulated as a result of this is so large that it is difficult for any one to assimilate the whole of it efficiently or in any way successfully, except perhaps as the result of prolonged study and experience. Nevertheless until the appearance of this book there has been no really comprehensive account of the biology of the rusts, and the student found himself severely handicapped by the unwieldy mass of literature confronting him. This difficulty is now removed by the excellent and comprehensive review given in this book together with the very extensive list, 57 pages long, in which the more important literature is cited.

After an opening chapter dealing with the general nature of rusts an historical review is given of the growth of knowledge and the development of research regarding them. This provides one of the most interesting and in some ways one of the most important chapters in the book, for it helps a proper perspective to be obtained of the vast edifice of research which has developed in modern times. Following this, development and classification are dealt with; the relationship of the rusts to the other main groups of fungi is considered, as well as their possible connexion in the past with the green, brown, or red algae. A summary is given of past and modern classifications, including those changes in taxonomy which the authors consider desirable in the light of modern knowledge. A useful section is devoted to the terminology of the rusts: that used throughout the book is of course the terminology already associated with the name of the senior author.

The next five chapters deal respectively with cytology and morphology, dissemination and geographical distribution, physiology, specialization, and tetratology and pathology. They constitute the main body of the book and are its most important part. The large ground here covered is dealt with in a clear and interesting manner and altogether these chapters constitute an excellent summary of the biology of the rusts. Those doing research in this field, or any generally interested in the biology of these fungi, will find them both useful and stimulating reading. There are many things here that no one who wishes to understand the rusts can afford to miss, or will find so usefully summarized elsewhere. The book closes with a chapter dealing briefly with the rusts that are of chief economic importance in agriculture and forestry, and another in which are described the methods

of investigation now commonly in use. The book is sufficiently and clearly illustrated; it is well produced and appears to be free from mistakes. The authors have undoubtedly produced a work of real service in the study of this important group of parasites.

The Formation of Spring and Summer Wood in Ash and Douglas Fir, by L. CHALK, M.A., D.Phil. *Oxford Forestry Memoirs*, No. 10, 1930.

Review by S. H. CLARKE.

ALL who are interested in the formation of the annual ring in trees, and its differentiation into spring and summer wood, will welcome this memoir for three reasons: firstly, because it brings new knowledge; secondly, because of the orderly manner in which the previous results of other workers are arranged; and thirdly, because the methods commonly used in this kind of work are discussed, and the accuracy of those used by the author is stated.

The memoir is divided into three parts. Part one describes the development of the ring in different trees and in different parts of the same tree. Part two deals with the effect of climatic conditions on the growth of Douglas fir, and part three with the effect of crown size on the production of wood in the same species.

Six trees of Douglas fir (*Pseudotsuga taxifolia* Britton, synonym *P. Douglasii* Carr.), and three each of common ash (*Fraxinus excelsior* L.), and of Italian ash (*F. oxycarpa* Willd.), were used in part one. They were carefully selected to cover the range of types in a particular plantation. Parts two and three deal with four of the Douglas fir trees, one of which was dominant, two intermediate, and one suppressed.

The development of the annual ring during the growing season was studied by extracting small cubical blocks from the trunk after successive regular intervals of time, and examining microscopic sections. In the ash there was a tendency for the south side to begin growth before the north, but no difference was observed between the upper and lower parts of the stem. Growth preceded the opening of the flower buds by a week, while 5–9 per cent. of the ring had been formed by the time the leaf-buds opened, and the ring was complete by the middle of August. In Douglas fir no appreciable difference was observed between the north and south sides of any tree, but the upper parts of the stem began growth 10–14 days before the lower. Growth in the stem preceded the swelling of the leaf-buds by about 12 days, while 4½–8 per cent. of the ring had been formed by the time that the terminal buds opened, and the ring was complete by the middle of September. These points are clearly illustrated by a graph, and also by the frontispiece, which consists of an ingenious arrangement of photomicrographs on a growth curve.

The development of the spring vessels in ash presents two points of great interest, in that these elements passed through a stage in which they were more or less crescent-shaped in transverse section, and that the vessels of the north side lagged behind those of the south, and did not reach quite the same diameter.

There are important objections to former methods of estimating the production of wood for correlation with climatic factors, namely, the use of ring width as opposed to volume, the consideration of the whole ring as a single unit, and incidentally of spring and summer wood as percentages of the ring. It is emphasized that the volumes of spring and summer wood were found to vary quite independently of each other. Close correlations were found to exist, on the one hand between the volume of spring wood and May–June mean temperatures, and on the other hand between the volume of summer wood and June–July–August rainfall.

In considering any particular ring it was found that in all cases the greatest cross-sectional area of both spring and summer wood occurred at the base of the crown, and from this point there was a decrease both upwards and downwards. The decrease towards the base was more marked in the suppressed than in the dominant tree, and in spring wood than in summer wood. In the dominant tree, the dry weight of the wood of the last four years was practically the same at all levels in the stem below the crown, but in the other trees it decreased towards the base. It was estimated that the amount of wood produced was 1½–2½ times the dry weight of the needles, and it appeared that the weight of wood produced was more closely related to the weight of the old needles than to that of the new needles.

Roadside Planting, by 'R. B. A.' (Roads Beautifying Association). Country Life, Ltd., London, 1930. *7s. 6d.*

Review by the Editor.

ONE of the less fortunate features of the post-war forestry development has been the drifting apart of those who are interested in commercial forestry and the arboriculturist, to use the term for those who are principally interested in the culture of trees for aesthetic reasons. This is quite understandable because the aims and methods of these two classes are, in part at least, quite different. The consequence of this is that many forest officers to-day have little or no interest in the aesthetic side of forestry, and no knowledge of its technique. We hope that this is a passing phase, because the forestry profession should lead in all that makes for the beautifying of the country by trees so that this aspect and the commercial aspect are harmonized as far as possible, and the knowledge of the country which forest officers possess is used when special aesthetic schemes have to be carried out. This cannot but lead to greater public support for commercial forestry.

This anonymous book, which apparently owes much to that eminent authority, Mr. W. Dallimore of Kew, will be invaluable to foresters, both in stimulating their interest in aesthetic forestry, and providing them with information to promote it.

The book opens with a general discussion of methods of planning roadside planting, drawn in part from experience in America, where much is now being done in this direction, and general information on establishment. Then follows an annotated list of suitable trees and shrubs. The subsequent chapters deal with trees and shrubs best adapted to particular environments or of a special category: suburban roads, spring effects, autumn effects, conifers, evergreen trees and shrubs, trees and shrubs for clay soil, for poor lime-free sandy soil, for chalky soil, for most situations, trees of a fastigiate habit, and trees of a weeping habit.

The book contains many beautiful illustrations.

NOTICES

Handbook of Geology of Great Britain. A Compilative Work, edited by J. W. Evans and C. J. Stubblefield. Thomas Murby & Co., London, 1929. 24*s*.

THIS is a new and extended edition of a similar work which appeared twelve years ago in a series called 'Handbuch der Regionalen Geologie' published in Heidelberg.

This country possesses excellent geological maps, while the memoirs of the Geological Survey explaining their maps give all available information for the different regions. There is, however, no recent general descriptive work dealing with the whole country, hence this volume will be welcomed by those interested in geology from applied standpoints such as forestry, although soils are not dealt with specifically.

The principal sections of the book are: Morphology, the Earthquakes of Great Britain, and Stratigraphy. In the last section, each of the systems from the Pre-Cambrian Group to the Quaternary Period is dealt with by an expert. Each system is dealt with for England and Wales and Scotland separately, and a bibliography given for each of the two political regions of the system. Hence all the available literature bearing on the geology of a system can be found quickly.

A Map of England and Wales, showing the Distribution of Glacial Erratics and Drifts, by F. W. Harmer, with a descriptive paper. Sold by John Bartholomew & Son, Ltd., Edinburgh. 10*s*., post free.

THIS is a beautiful map showing contours in colour and the distribution of the different drifts and erratics in distinctive colours and symbols.

Glacial geology has had such an influence on soils in this country north of the Thames Valley that a map of this kind deserves to be brought to the notice of foresters. The scale, sixteen miles to one inch, is too small to give local details, but the map illustrates very clearly the general movements which resulted in the deposition of drift and erratics, and gives some clue to the soil characteristics of the different drifts.

Insects and Industry, by J. W. Munro. Benn's Sixpenny Library, No. 95.

THE great success of Benn's Sixpenny Library is due probably to the desire of many people to read something informative or stimulating on a railway journey. Whether for such occasion or any other, foresters will find much to interest them in this contribution by Dr. J. W. Munro. Although the importance of insects in many branches of industry is dealt with, forestry bulks largely, as the result of the author's special interest in this subject. It will probably be a surprise to many to learn of the increasing importance of economic entomology in so many industrial fields.

Empire Forestry Handbook, edited by Fraser Story, 1930. Published by the Empire Forestry Association, London. 3*s*. 6*d*.

THIS well-bound volume brings together a considerable amount of information of interest and use to foresters. The following are the sections of the publication: The Empire Forestry Association, complete information; Forest Officers of the Empire,

arranged under the administrative regions of each political unit; Departments and Institutions dealing with Imperial Forestry; Education and Research, the staffs and research programmes of research institutes are given; Trade names of Empire timbers.

Webster's Foresters' Diary and Pocket Book, 1930.

THIS diary as usual contains much information which foresters need every day.

OBSERVATIONS ON *ARMILLARIA MELLEA* IN PURE CULTURE WITH CERTAIN CONIFERS

BY M. C. RAYNER

INTRODUCTORY.

ARMILLARIA MELLEA, the Honey Agaric, is well known to foresters as a common and often destructive parasite of broad-leaved and coniferous trees. Inconsistency in the incidence and severity of attack is a notable and puzzling feature of its behaviour revealed by even casual inspection of woods where the rhizomorphs are known to abound.

Since this fungus is a woodland species of wide distribution, persisting as a saprophyte on the remains of dead roots and stumps, but capable of behaving as a virulent parasite to trees of many different species, it is of great importance to ascertain the factors that underlie and determine the degree of parasitism it displays. The known facts have recently been summarized by Day (2), who points out that the fungus appears in two roles as a parasite. In one it is a secondary pathogen, attacking only trees weakened by disease and adverse conditions; in the other it behaves as a virulent parasite, killing apparently healthy trees. 'It is noteworthy', he continues, 'that when so acting the fungus is always reported as attacking crops that have been artificially regenerated or grossly interfered with by mankind. It is quite possible that in natural forest the fungus frequently acts in this second role, but if this has been observed it does not appear ever to have been recorded. Is the fungus really a virulent parasite on healthy trees, and why does it so frequently appear to assume this role in artificially established forest and in plantations? There are two lines of inquiry that will help to throw light on these questions. The first seeks to determine what factors are associated with attack by *Armillaria mellea* on apparently healthy trees; the second to establish what is the relative susceptibility of different hosts, and whether the degree of susceptibility ever varies.'

It was with the object of obtaining experimental evidence relating to these problems that the writer—before publication of the paper just quoted—undertook an experimental inquiry into the reaction to *Armillaria* shown by seedlings of certain conifers in pure culture.

The work was begun with two definite objectives:

a. To ascertain whether seedlings of different coniferous species vary in respect to susceptibility under pure culture conditions.

b. To observe the mode of attack in parasitized seedlings, to estimate the degree of virulence displayed by the fungus, and, in an extended series of cultures, to learn something about the factors influencing the behaviour of parasite and host.

No information based on experiment was available in respect of any of these

matters. It had, however, been suggested by Day (1) from observations on the incidence of attack in the field 'that certain species and genera of conifers appear fairly consistently to be more susceptible to attack by *Armillaria mellea* than are others', although 'susceptible species growing in close proximity to an abundant growth of the fungus sometimes are not attacked' and 'species generally reckoned among the more resistant are sometimes attacked but not killed'.

To the student of mycorrhiza, *Armillaria mellea* as a root parasite has features of special interest. It is a member of the group to which belong the great majority of species known or suspected to be responsible for forming mycorrhiza in trees. Moreover, there is on record one case in which it has established with an herbaceous flowering plant a symbiotic association reciprocal in character and apparently of a relatively balanced kind. The plant in question is *Gastrodia elata*, a non-chlorophyllous orchid of remarkable habit, native in Japan. The observed facts relating to its association with *Armillaria mellea* were described by Kusano (3) and his interpretation of them has not been questioned. Kusano concluded that the orchid could reach the flowering stage and so complete its development only by parasitizing the attacking fungus, thus establishing a relation of balanced parasitism with the profit ultimately on the side of the flowering plant. If the facts are correctly interpreted, the course of events in this case suggests that the behaviour of *Armillaria* is determined by the reaction shown by the host to invasion of its tissues.

It seemed possible, therefore, that pure culture experiments of the kind contemplated might also yield some information throwing light on the origin of the mycorrhizal habit in trees.

PURE CULTURE EXPERIMENTS.

The species selected for pure culture as representing hypothetical extremes of susceptibility and resistance were Corsican pine (*P. laricio* var., *Corsicana*. London) and Douglas fir (*Pseudotsuga Douglasii*), Carr. The comparatively limited field observations available point to species of *Pinus* as highly susceptible both in respect to incidence of attack and subsequent death of the trees. On the other hand, Douglas fir is apparently relatively resistant both to attack and its consequences (Day (1)).

Seeds of both species were carefully hand-picked to ensure undamaged seed-coats, sterilized and sown in small flasks under conditions capable of testing their freedom from contamination. A week or so after germination the resulting seedlings were transferred singly to sand cultures in specially designed vessels in which the rooting medium was inoculated at planting with small pieces of young rhizomorph from an actively growing culture of *Armillaria mellea*. Strict asepsis was observed in all these operations. The strain of fungus used was isolated by planting out pieces of a young sporophore growing naturally in woodland and sub-culturing the resulting growths to suitable media. The cultures actually used for inoculation had been sub-cultured on malt agar or potato agar and were cultivated continuously upon the former medium during the period occupied by the experiments. Sub-culturing was done with

small pieces of rhizomorph, and all cultures so made continued to produce rhizomorphs in great abundance. (Fig. 1.)

The observations now summarized are based on several successive series of pure cultures maintained free from contamination for periods varying from thirteen months to two and a half years. Their behaviour was checked by that of uninoculated controls in pure culture and also by that of seedlings grown in inoculated and uninoculated pot-cultures of ordinary soil.

The actual procedure adopted in pure culture work was as follows :

After hand-picking, seeds were immersed in 1 per cent. mercuric chloride for three to four minutes, rinsed repeatedly in sterilized water, and transferred in batches of six to small flasks containing nutrient agar. The use of a seed-bed containing sugar and peptone in addition to mineral salts acted as an efficient check upon faulty sterilization. Preliminary trials were made with various sterilizing agents in varying concentrations; the use of 1 per cent. mercuric chloride for strictly limited periods followed by adequate rinsing of the seeds was found to give satisfactory results. Seeds sterilized in this way germinated at the same rate as untreated seeds, and seedlings raised from them showed perfectly normal growth. (Fig. 2.)

Various types of culture vessel were tried. Some of the earlier cultures were grown in large U-tubes fitted as shown in Fig. 3. This type of vessel has the advantage of satisfactory aeration of the rooting medium, but is difficult to handle without an undue proportion of breakages and can be used only for relatively short growth periods. All the later cultures were grown in the double flasks illustrated in Figures 5 and 6. These permitted an adequate supply of culture solution and gave sufficient headroom for long-period cultures. Irrigation of the cultures from the watering flask and drainage of superfluous liquid back into the latter could be used as a means of testing the purity of the cultures and demonstrating the freedom of sand and solution from accidental contamination by micro-organisms. It provided also ocular demonstration of the growth of the inocula, and pure cultures of *Armillaria mellea* were recovered in this way from many of the watering flasks. Apparatus and sand were cleaned by standard methods. After filling with the requisite amounts of sand and nutrient solution the tubes or flasks were autoclaved at 120° C. for thirty minutes and allowed to stand for some days before planting.

The constitution of the nutrient solution was as follows:

Potassium phosphate (KH_2PO_4)	2 grams.
Calcium chloride ($CaCl_2$)	0·2 „
Sodium chloride (NaCl)	0·2 „
Magnesium sulphate ($MgSO_4$)	0·6 „
Potassium nitrate (KNO_3)	1·6 „
Iron chloride ($FeCl_3$)	0·1 % solution, 3 c.c.
Distilled water	2,000 c.c.

The pH value of this solution was about 5 (4·6–5·2).

At planting, the sand in each flask was inoculated about one inch from the base

of the seedling with a piece of young rhizomorph 0·5 to 1 cm. in length. Control flasks were similar in all respects but were not inoculated. The cultures were grown in a small roof greenhouse warmed sufficiently in winter to exclude frost. In very dark or foggy weather they were artificially illuminated for two or three hours daily by a gas-filled 100-watt lamp. Under these conditions, seedlings of both species made perfectly satisfactory growth ; some were still growing and relatively healthy after two and a half years from planting. (Figs. 4, 5.)

CORSICAN PINE. PURE CULTURES.

Records from two series of cultures are available and the results may be considered separately. In the first, seedlings were grown in U-tubes and the longest period of growth was thirteen months. A fair proportion of these cultures were lost after a month or so from breakage of the tubes. As might also be expected in a preliminary series, a number became contaminated casually by moulds or bacteria either at planting or subsequently. As shown by subsequent examination, the behaviour of most of the seedlings in contaminated flasks was identical with that of those in which purity was maintained. The following summary and the photographs illustrating it (Figs. 3, 4) refer only to the latter.

Mortality from accidental or unknown cause was considerable in the early stages of these cultures affecting control plants in equal or even greater degree. All the surviving seedlings remained healthy and vigorous for eight or nine months after planting and inoculation; no difference in vigour, colour, or rate of growth could be detected between those in inoculated cultures and controls. At the end of sixteen months' growth (March, 1927, to July, 1928) the seedlings in inoculated tubes were still green and apparently healthy, but all showed characteristic corky 'cankers' at the base of the stem at or above the level of the sand, and they were fixed for examination. They averaged 7 to 8 cm. in height from sand level to the tip of the terminal bud; in most, the main roots were from 30 to 35 cm. long with normal branching. A representative seedling is shown in the photograph reproduced, which shows well the vigorous root growth and apparently unimpaired health (Fig. 4). Rhizomorphs were not formed in any of the cultures. On removing seedlings from the tubes, it was found that small cankers similar in appearance to those on the stems were also present on the roots. Here they were practically confined to the neighbourhood of emerging laterals, varied in size, and sometimes caused considerable distortion of the root. (Figs. 7, 8.)

Structurally, these cankers bear a curiously close resemblance to ordinary lenticels. They are provoked by contact and penetration of mycelium of the parasite, and represent the immediate response shown by the neighbouring tissues to infection by suberization of the walls and the rapid formation of new cork.

In roots, the rupture caused by emergence of a lateral root facilitates infection, penetration of the outer tissues taking place either by isolated hyphae or by branches from a closely adpressed sheet of mycelium comparable in structure

to the xylostroma described in attacks upon older trees under natural conditions (Day (1)). (Fig. 9.)

Fine mycelium of the parasite was present in the loose corky tissue towards the outside of the canker but showed no tendency to spread in a lateral direction. Penetration of the living cortical cells beneath the canker at this stage was absent or very rare. Stem cankers were identical in structure, differing only in the relatively larger amounts of cork formed. Whether this indicates greater activity in the rate of cork formation in this region or depends merely upon the length of the period subsequent to attack could not be determined. Since no evidence was found of continuous tissue infection extending laterally from root cankers, it must be assumed that each canker represents an isolated focus of attack. The relatively large size of those formed near the base of the stem suggests that infection of this region from without took place independently at a relatively early stage of the attack. (Cf. Fig. 7.) The structure of the cankers and relative paucity of mycelium present is well shown in the photographs in Plate II (Figs. 10, 11).

The second series of cultures were grown in double flasks under similar conditions, a larger number were planted, and there were few losses from breakage or casual contamination. Mortality from unknown causes at an early stage was not severe and affected controls equally. In general, the seedlings were healthy and vigorous during the first twelve months after planting and inoculation, and no difference in vigour or rate of growth was detectable in inoculated cultures as compared with controls. (Figs. 5, 6.) No stem cankers appeared in any of these seedlings, and so far as could be observed none were present on such roots as could be examined through the flasks from below. Growth fell off during the second year, but it is difficult to estimate to what extent this was due to accumulation of by-products in the flasks. Two seedlings (that shown in Fig. 6 and another) were still relatively healthy when the cultures were brought to an end twenty-six months from planting. After removal from the flasks, microscopic examination of these seedlings showed that incipient 'cankers' were beginning to form just below the surface, marking the points of emergence of young adventitious roots. Incipient cankers could also be detected at the bases of a few of the young laterals. Mycelium of the parasite was *very sparingly* present in and about the external corky tissues at these points, and also elsewhere in close proximity to the epidermal cells of younger parts of the root.

DOUGLAS FIR. PURE CULTURES.

Seedlings of Douglas fir thrived equally well under pure culture conditions. During the first year no difference could be detected in the behaviour of seedlings in inoculated flasks as compared with controls. Both were healthy and vigorous with fresh green needles and satisfactory root growth. (Fig. 12.)

At twelve months from planting all the seedlings in inoculated flasks showed the characteristic corky 'cankers' at or near the base of the stem indicating local invasion of the tissues. (Fig. 13.)

In some the general health was apparently unaffected, in others the young leaves showed a fluctuating degree of chlorosis.

These localized 'cankers' showed no tendency to spread, and after several months it was apparent that the affected area had been completely exfoliated by the formation of cork continuous with that over the rest of the stem. Microscopic examination after removal from the flask confirmed this, and sections through the affected region showed no infection of the cortical tissues below the original point of infection. The 'cankers' were identical in structure with those of Corsican pine; each was formed as the result of an active formation of cork locally, following invasion of the normal corky tissue by mycelium. In these Douglas fir seedlings the 'corking out' process was apparently very effective, although the young shoots showed indications of a toxic effect more markedly than was the case in similarly affected seedlings of Corsican pine.

The seedlings developed a normal root system with main roots from 20 to 25 cm. in length. These showed no trace of canker formation associated with emergence of the laterals as in Corsican pine. In some roots the younger parts showed slight local thickenings, and these areas, on sectioning, provided evidence of relatively light local infection by mycelium of the parasite, fine hyphae forcing a way between the epidermal cells and occasionally invading the root-hairs. Such attack was immediately met by local suberization of the cell-walls and exfoliation of the attacked tissues. Infection was not observed to extend to the deeper tissues, and the general impression given by these seedlings was that a very effective resistance was offered by the roots to invasion. The attack appeared to be confined to the younger parts previous to cork formation, and must therefore have taken place subsequently to that causing the stem cankers. A 'mat' of actively growing mycelium of the parasite was present in the watering flasks of many of the cultures.

SUMMARY OF OBSERVATIONS ON PURE CULTURE.

These cultures of Corsican pine and Douglas fir permit the following conclusions:

a. Rhizomorphs of *Armillaria mellea* continue to grow as *mycelium* under pure culture conditions in sand irrigated with a nutrient solution containing only inorganic salts. Observations on the behaviour of the inocula in cultures containing seedlings that died from accidental causes soon after planting suggest that the proximity of a growing plant influences the activity of the fragment of rhizomorph used as an inoculum in respect to growth.

b. Seedlings of Corsican pine enjoy a long period of immunity after inoculation of the substrate by the fungus. The appearance of stem cankers due to local infection at the end of twelve months, and the relative abundance of similar cankers on the roots at the emergence of laterals in one series, provided evidence of relatively heavy attack met by a very efficient suberizing and 'corking out' mechanism on the part of the seedlings. A second series were maintained in pure culture for twenty-six months after inoculation of the

flasks, without giving any visible reaction to infection in the form of stem or root cankers. Microscopic examination showed, however, that incipient 'cankers' were beginning to form on the roots and just below the surface of the sand. There is no obvious explanation of the greater resistance to infection shown by the second series of Corsican pine seedlings. Its possible significance is discussed later (p. 72).

c. Seedlings of Douglas fir also enjoy a long period of apparent immunity. Stem cankers due to local infection met by a 'corking out' reaction on the part of the seedlings appeared at the end of twelve months. During the nineteen months that the seedlings were maintained in pure culture the mild attack made locally upon the roots was effectively met by local suberization with excision of the epidermal and root hair tissues. It was not so severe as to provoke local cork formation on a scale sufficient to give rise to 'cankers'. In old cultures some evidence of damage from toxic poisoning was provided by chlorosis and browning of the young shoots.

In respect to these cultures a possible criticism may be anticipated. The view that mycelium of the fungus is not likely to grow normally in solutions containing inorganic salts only can be tested by duplicating such cultures as have been described, adding suitable organic substances. The effects produced by such additions on growth of *Armillaria* mycelium have not yet been fully explored, but it may be placed on record that the addition of sugar and peptone or asparagin to the solutions used for irrigation has not provided evidence that the parasitic powers of the mycelium are affected in any way by the addition of these organic substances to the inorganic solution used. On *a priori* grounds it might be expected that mycelium of a facultative parasite deprived of organic food would the more readily attack living roots.

The use of natural humus instead of sand as a rooting medium has not been tried because, unfortunately, humus, heat-sterilized by the ordinary methods, is known to be toxic both to roots and to fungus mycelium (Rayner (5), Melin (4)). It remains for future researches to devise methods by which humus soil in a culture vessel can be sterilized effectively *in situ* without rendering it unsuitable for plant growth.

POT CULTURES.

The behaviour of seedlings in pure culture has been checked and the observations on infection supplemented by that of pot cultures in ordinary garden compost.

Seeds of both species were sown in pots of compost containing a high proportion of humus in the form of leaf-soil. When the seedlings were several months old, the soil in each pot was inoculated in two places with small pieces of rhizomorph from a pure culture of the fungus. Duplicate series were grown, one in untreated soil, the other in the same soil heated for some hours at 100° C.

No difference in behaviour has been observed in the two series with respect to infection, but the growth of all seedlings in the partially sterilized soil was markedly better and the improved growth observable persisted for at least one

year from sowing. During the summer these pot cultures have been grown in the open in a London park, some attention being paid to keeping the foliage clear of sooty deposit, and they have been wintered in a small roof greenhouse, warmed sufficiently to exclude frost.

No difference has been detectable in the growth and vigour of seedlings in pots inoculated with the fungus. During the second year a majority of the Corsican pines were lost owing to repotting too late in the season. The mortality thus caused was equally heavy among controls, and, fortunately, both classes are represented among the survivors. At the time of writing, three years from the date of inoculation, the experimental plants of both species are still growing and apparently healthy. No stem 'cankers' have appeared and no chlorosis or browning of the shoots has been observed. Examination of the roots from sample pots shewed a normal root system, save for the absence of mycorrhiza. Fine mycelium identical in appearance with that of *Armillaria mellea* was sparingly present about the young roots, but there was no sign of parasitic attack and no 'cankers' or lesions of any kind. The ability of the rhizomorphs to form mycelium in the soil used for potting had been previously tested in laboratory cultures. Rhizomorphs have not been observed in the sample pots examined. (Figs. 14, 15, 16.)

Cultivation in London imposes certain conditions known to be unfavourable to the growth of conifers; on the other hand, these cultures received cool greenhouse conditions in winter and were thus partially protected from sooty deposits on the foliage and from unfavourable weather.

CONCLUSIONS AND DISCUSSION.

The evidence relating to differential susceptibility in coniferous species provided by these pure culture experiments is significant although not conclusive.

The plants in one series of cultures of Corsican pine all showed obvious signs of attack in the form of stem cankers after twelve months. Attack on the roots was relatively heavy and focused at the emergence of laterals. The plants kept the attack in check by suberization of the neighbouring cells and active formation of cork.

The indication of relative susceptibility thus provided was apparently contradicted by the behaviour of a second series of Corsican pine, in which none of the plants showed any obvious symptoms of attack after more than two years' growth in contact with mycelium of the parasite. The two series of cultures were grown in different types of culture vessel and in successive years; otherwise conditions were identical. The difference in the behaviour of seedlings in the two series was more apparent than real, and the longer period of immunity enjoyed by those in the second series may have been due to seasonal differences or possibly to improved conditions for growth in the different type of culture vessel used.

After twelve months all pure culture seedlings of Douglas fir showed stem 'cankers', most of which were obliterated later by excision of the infected bark and formation of a continuous layer of new cork. Attack on the roots was

limited to the superficial tissues of the younger regions and was met effectively by suberization and excision of the affected cells. Neither Corsican pine or Douglas fir showed symptoms of bad health for at least one year after planting. Chlorosis or browning of the young foliage occurred in older plants of the latter, but it is difficult to estimate to what extent the apparent lowering of resistance so indicated was caused by conditions directly related to the age of the cultures.

Pot cultures of both species subjected to inoculation have grown for three years without exhibiting any symptoms of ill health or signs of attack.

In general, the behaviour of experimental plants is interpreted as indicating a relatively high degree of resistance in both Corsican pine and Douglas fir easily impaired by unfavourable factors in the environment. It is not believed that it affords any support for the hypothesis of differential susceptibility in the two species, but suggests rather that control of *Armillaria mellea* in the field is bound up with the provision of optimum environmental conditions, thus permitting the maximum development of naturally high powers of resistance. These conclusions are in agreement with those reached independently by Day (2) on a basis of field observations.

The possibility of inherent differences due to natural variation must not be overlooked. Any commercial sample of conifer seed may, and probably always does, include representatives of races or strains differing from one another in minor details of morphological structure and also in physiological qualities. Among the latter a different degree of resistance to particular parasites may distinguish strains or even individuals. Variation of a similar kind may occur likewise in the fungus giving rise to strains varying from extreme virulence to relatively weak powers of parasitization.

In such natural variation, playing its part both in the host trees and the attacking fungi, must doubtless be sought the origin of the mycorrhizal habit in trees; perhaps likewise the basis for selection of such qualities as determine degrees of virulence and powers of resistance in parasite and host respectively.

With regard to the bearing of these experimental observations on the evolution of the mycorrhizal habit, it is clear that stages resembling those described in the roots of Douglas fir seedlings attacked by mycelium of *Armillaria* may have been represented in that evolutionary series, since the habit of forming fungus roots must have originated in parasitic or *quasi* parasitic attack on the part of certain soil fungi. It may even be worth speculating whether mycelium of *Armillaria* is capable of forming a relatively stabilized association with roots of certain coniferous species or strains, comparable with the balanced parasitism reported for *Gastrodia*, or the one-sided and undesirable type of fungus root described by Melin as *pseudomycorrhiza* (Melin (4)).

While contributing to our knowledge of the mutual relations of parasite and host, it is evident that conclusions based on experiments with pure cultures must be applied with great caution to conditions in nature. The experimental plants are subjected to relatively abnormal conditions—saturated atmosphere, imperfect aeration of the rooting medium, and a supply of nutrient salts

strictly limited and controlled. At the same time, they are sheltered from competition and protected from frost and the rigours of winter conditions in the open.

In respect to the nutrient, recent work has modified the view of plant physiologists as to what constitutes a complete culture solution by providing evidence that elements, hitherto regarded as of no importance, may play an important part in plant nutrition. Boron, in minute quantities, is essential to the healthy growth of certain plants, and recent research has shown that manganese in very dilute concentration controls the intake of calcium and potassium by the oat plant and that serious disease may be caused by its absence from the source of food supply. On the other hand, these experimental coniferous seedlings had at their disposal relatively large seed reserves, they grew vigorously, especially in the early stages, and it may fairly be assumed that the formal conditions for healthy growth were provided.

In respect to the fungus, it is possible that the mycelium may suffer physiological change when grown in pure culture on synthetic media, although in nature *Armillaria mellea* grows habitually as a saprophyte as well as parasitically. The formation of rhizomorphs is known to be a reaction to drought in the environment and can be controlled experimentally (Day (2)). The relatively moist conditions in the experimental flasks might be expected to inhibit rhizomorph formation, and this was presumably the case since it was not observed in any culture. The possibility or otherwise of a direct relation between rhizomorph formation and virulence of attack can be determined only by further experiments, varying the constitution and reaction of the rooting medium in an extended series of cultures.

On the whole, it may be concluded that the conditions provided, in so far as they differed from the normal, acted as a handicap to the seedlings rather than the fungus. In view of the uniformity of results in any one series and their similarity to those yielded by pot cultures, certain conclusions may be offered as a basis for discussion.

In the first place, the observations demonstrate conclusively that, under the conditions provided, mycelium of *Armillaria mellea* can and does attack conifer seedlings parasitically. It is clear, moreover, that even under the relative handicap imposed by pure culture conditions, seedlings of Corsican pine and Douglas fir are relatively resistant to such attack and can effectively combat it by means of a vigorous 'corking out' mechanism. This appears to serve as an effective check to further parasitization, although both in these cultures and in nature mycelium penetrates corky tissues and vegetates within them. The attack made on the experimental seedlings was relatively mild, the general impression derived from close study of them being that virulence of attack is determined rather by the reaction of the host and the character of the environment than by any inherent quality of the parasite. In view of the inconsistencies observed in plantations, it would be of interest in this connexion to have more complete data as to the relative susceptibility of various exotic conifers in this country and elsewhere.

Melin's observations on the effects of root association with species of *Boletus* in excluding undesirable soil fungi suggest that it is likewise desirable to obtain evidence concerning the effect of normal mycorrhizal infection upon susceptibility to attack. It is obvious that change of habitat of the drastic kind involved in acclimatization of exotic conifers used in afforestation in this country and elsewhere must involve great disturbance of the biological associations formed by these species in their native habitats. It is possible that trees normal in respect to their mycorrhizal equipment may be more resistant to attack, thus exemplifying one of the factors responsible for inconsistency in the incidence of attack in plantations.

It seems not improbable that the conifers succumbing to *Armillaria* in nature form but a small proportion of the individuals attacked, and that careful examination of the root system of healthy trees, if practicable, might often reveal old lesions resembling the healed stem cankers observed in seedlings of Douglas fir.

The day is long past when the incidence and severity of parasitic disease can be held to depend entirely or even mainly upon proximity of the attacking organism to the host. It is recognized that susceptibility is frequently due to some lack of balance in the metabolism of the victims, often provoked directly or indirectly by unfavourable factors in the environment. Not many cases in plant pathology have yet been subjected to close analysis. One of exceptional interest was reported recently in relation to 'Seedling Blight', a parasitic bacterial disease of young cereals. Here it was found that susceptibility or resistance could be determined experimentally by varying one factor in the environment; viz. temperature. Grown at high temperatures, seedlings of wheat are very susceptible; at the same temperature, maize seedlings are resistant, but become susceptible at the lower temperature most favourable to wheat.

The immediate cause of increased susceptibility is the same in wheat and maize; viz. a disturbance of metabolism resulting in the formation of pentoses instead of ordinary sugars and an accumulation of nitrogenous material (asparagin) not occurring normally. The protective mechanism in resistant plants consists in rapid suberization of the attacked tissue, i.e. a very efficient 'corking out' process. This is immediately impaired by the metabolic disturbance mentioned, rendering the plants extremely susceptible.

It is not suggested that an exact parallel exists in the case of Conifers and the Honey Agaric, but it is evident that seedlings possess naturally an efficient defence mechanism of a similar kind, and the inconsistencies observed both in cultures and in nature suggest that the degree of efficiency may be very readily affected by slight changes in the environment.

I have to acknowledge the kindness of Mr. W. R. Day in supplying me with the original cultures of *Armillaria mellea* from which those used for supplying the inocula were derived.

SUMMARY.

1. The susceptibility of Corsican pine and Douglas fir to attack by *Armillaria mellea* has been tested by growing seedlings in pure culture, inoculating the rooting medium with rhizomorphs from an actively growing culture of the fungus.

2. Seedlings of both species enjoy a long period of apparent immunity. When attacked they exhibit active resistance by thickening and suberizations of cell-walls and rapid formation of cork, resulting in the appearance of stem and root 'cankers' at the points of attack.

In Corsican pine, attack on the roots was focused at the emergence of lateral roots.

3. Corresponding pot cultures have been cultivated for three years without showing any signs of attack.

4. The bearing of these observations on the inconsistencies of attack observed in the field is discussed.

It is believed that they provide support for the view that the virulence of *Armillaria mellea*, as a parasite of Conifers, is determined by the reaction of the hosts and character of the environment rather than by any inherent quality of the fungus.

5. The possibility that strains of the host trees varying in degrees of resistance or susceptibility and strains of *Armillaria mellea* varying in degrees of virulence exist in nature must not be overlooked.

REFERENCES

(1) Day, W. R.: 'Parasitism of *Armillaria mellea* in relation to Conifers.' *Quarterly Journal of Forestry*, 1927, p. 1.

(2) Day, W. R.: 'Environment and Disease.' *Forestry*, vol. iii, 1929, p. 94.

(3) Kusano, S.: '*Gastrodia elata* and *Armillaria mellea*.' *Journal of College of Agriculture, University of Tokio*, vol. iv, 1911 (see also *Annals of Botany*, vol. xxv, 1911, p. 522).

(4) Melin, Elias: *Untersuchungen über die Bedeutung der Baummykorrhiza*. Gustav Fischer, Jena, 1925.

(5) Rayner, M. C.: 'The Multiple Mycorrhizas of Trees.' *Forestry*, vol. iii, 1929, p. 26.

EXPLANATION OF PLATES II AND III

PLATE II

FIG. 1. *Armillaria mellea*; pure culture on malt agar. Rhizomorphs viewed from under side of colony.

FIG. 2. Corsican pine; pure culture in seed flask. Two months from sowing.

FIG. 3. Corsican pine; pure culture in U-tube. Three months from planting, sand inoculated rhizomorphs of *Armillaria mellea*.

FIG. 4. Corsican pine; same seedling as shown in Fig. 3. Nine months from planting. × $\frac{1}{5}$.

FIG. 5. Corsican pine (second series); control seedling in pure culture in flask. Fourteen months from planting. × $\frac{1}{6}$.

FIG. 6. Corsican pine; seedling of identical age and history with that shown in Fig. 5, but sand inoculated at planting with rhizomorphs of *Armillaria mellea*. × $\frac{1}{6}$.

FIG. 7. Corsican pine; pure culture seedling shown in Figs. 3 and 4. Thirteen months old when removed from culture tube. Base of stem and upper part of roots showing 'cankers'. × 4.

PLATE II

PLATE III

FIG. 8. Corsican pine; portion of root showing lateral root with 'cankers' at point of emergence. × 11.

FIG. 9. Corsican pine; transverse section of root showing early stage of attack by mycelium of *Armillaria mellea*. The mycelium forms a closely interwoven stroma, *m*, adpressed to the outer tissues. The reaction of the root is shown in thickening and suberization of the adjacent cell-walls and consequent distorsion of the cells. A stage antecedent to cork formation.

FIG. 10. Corsican pine; longitudinal section of main root through 'canker' area at emergence of lateral. The section shows lateral root in slightly tangential section, corky tissues in contact, and mycelium of the parasite in and about the outer cork and emerging rootlet.

FIG. 11. Corsican pine; longitudinal section tangential to emerging lateral. More highly magnified than Fig. 10 to show details of cork and mycelium, *m*.

PLATE III

FIG. 12. Douglas fir; pure culture seedling one year from planting in flask. Sand inoculated at planting with rhizomorph of *Armillaria mellea*. × $\frac{1}{5}$.

FIG. 13. Douglas fir; base of stem more highly magnified to show 'cankers'.

FIG. 14. Corsican pine; pot cultures two years and ten months from sowing: (1) soil, partially sterilized, inoculated with rhizomorph of *Armillaria mellea*; (2) control, same age, soil partially sterilized, not inoculated; (3) control, same age, soil untreated, not inoculated.

FIG. 15. Douglas fir; pot cultures two and a half years from sowing. Controls, soil partially sterilized, not inoculated.

FIG. 16. Douglas fir; pot cultures, same age and history as those in Fig. 15, but soil inoculated with rhizomorph of *Armillaria mellea*.

THE PROBLEM OF FIRE IN BRITISH FORESTS

BY W. L. TAYLOR
Forestry Commission

THE menace of fire in the forest, its prevention, and the fighting of forest fires, when they occur, are matters of prime importance to forest officers and foresters in charge of the new British forests. Fire prevention and fire control will inevitably provide some of the most difficult practical problems of the second decade of State Forestry in Great Britain.

TYPES OF FOREST FIRES.

Forest fires may be placed in three categories:

(*a*) Surface Fires.
(*b*) Crown Fires.
(*c*) Sub-surface Fires.

Nearly all forest fires commence as surface (or ground) fires, through the ignition of the dead grasses and weeds which occur over almost all newly planted areas and which are often to be found, at certain seasons of the year, in the vicinity of established plantations. When once alight, a surface fire will spread with great rapidity, even if fanned by only a moderate wind. At Margam in Glamorganshire, in the month of March 1929, a surface fire travelled half a mile in seven minutes according to the observation of those on the spot, no less than 697 acres of young conifer plantations being wiped out on this occasion. A fiercely burning surface fire reaching a plantation emerging from the thicket stage, or older, rapidly becomes a crown fire. Fire envelops and consumes the crowns of the trees, spreading from crown to crown, and the danger to a coniferous forest in such circumstances is a frightful one. Crown fires can also arise directly from the careless lighting of fires within the woods and from the burning of lop and top or rubbish under unsuitable conditions of locality, weather, and supervision. The sub-surface (or subterranean) fire is a less frequent type. Almost always it originates also as a surface fire and may occur whenever a layer of dry peat or dry humus exists below the surface of the ground. Such conditions are to be found on certain of the heaths of the east and south of England and on some of the drier moors of the north. These sub-surface fires may persist for long periods in a smouldering condition, their activity being only betrayed by an occasional vent at the surface, and the danger of a further outbreak as a surface fire is present all the time.

DAMAGE DONE.

The damage done by a forest fire is the destruction of, or permanent injury to the crop, with the resulting serious capital loss. In the case of a fiercely

burning surface fire over an area of newly planted ground, the destruction of the trees is generally immediate and complete and, even where weed-growth is sparse and the fire passes quickly over the ground, the injury to the cambium is usually sufficient to cause the death of the young trees within a short period. The thicker-barked species can, in the later stages of growth, withstand a considerable degree of scorching without serious effect. Broad-leaved trees, when past the thicket stage, stand in less danger from fires than the conifers. An exception is beech, a thin-barked tree, which nevertheless is often prescribed for planting in firebelts because of its dense and early canopy, and the consequent killing out of the ground vegetation. One reason why broad-leaved trees are to be considered less subject to fires is that they are usually planted on the better soils which are more retentive of moisture; another is that, with few exceptions, they are inherently of a less inflammable nature than the resinous conifers, and generally the various broad-leaved species have stronger recuperative powers than the coniferae.

In cases of crown fire, the destruction of the stand follows from the actual burning of the trees or their crowns. Where the fire is not so fierce as to kill the stands outright, damage can manifest itself in other ways. A slowing down of the rate of annual growth may occur for a period, and where a proportion only of the trees is actually lost, a reduction in density of stocking will result. Loss of production or quality, and often of both, must be faced in either case. Natural regeneration can also be hindered by the destruction of seed bearers, seeds, and seedlings, and a further possibility of serious damage to the forest arises, in conifer plantations, from enhanced danger from insect pests, notably *Myelophilus piniperda* and *Hylobius abietis*, for which the partially burned stems remaining on the ground afford favourable breeding conditions. If only for this reason burnt-over areas should be cleared with the least possible delay.

The passage of a fiercely burning fire over the ground surface can alter very materially the conditions making for fertility of the soil by destroying the humus layer and laying bare the mineral soil; also a surface fire will, not infrequently, effect changes, usually of an adverse character, in the natural flora. Examples of the action of fire in this way may be observed on grouse moors from time to time when the burning of heather has been carried out under unsuitable conditions of season or weather—*Calluna*, the new growth of which the fire is designed to encourage, being replaced by the often subdominant *Vaccinium myrtillus*, or by undesirable species such as *Juncus squarrosus*, *Scirpus caespetosus*, and *Eriophorum* spp. In the forest, the impoverishment of soil through the action of fire is a secondary danger of considerable financial importance.

INFLUENCE OF SURFACE VEGETATION.

All natural associations of ground vegetation are capable of drying out and becoming inflammable at some season of the year, and thus giving rise to danger from fire. Certain plants and natural plant associations are more

dangerous than others in this respect, but, given suitable meteorological conditions at any period after the completion of the annual growth of the weed plants and before the new growth appears in the late spring, the hazard is always a serious one. Under such conditions bracken, grasses, sedges, and rushes can all become extremely easy to ignite; heather and gorse will burn fiercely living or dead; mosses and even lichens (*Cladonia* spp.) become highly inflammable. Possibly worst of all from the point of view of inflammability and rapid combustion is the grass, *Molinia caerulea*, the thickly standing bents of which form almost the whole vegetation on many thousands of acres of afforestable land of the so-called 'white moor' types of the north of England and elsewhere. An additional danger from *Molinia* is the facility with which its dead (and burning) leaves can be borne ahead by the wind, enabling fires to leap fire traces and generally widening the zone of immediate danger. It is not without reason that this grass is known in parts of the country as the 'blow grass' or 'blowing bent'.

INFLUENCE OF METEOROLOGICAL AND SEASONAL CONDITIONS.

The variability of the British climate is proverbial, and no period of the year can safely be said to afford immunity from forest-fire risks. The worst months in Britain are March and April; and danger is also serious in May and in the late summer. It has, however, lately been recorded that the most disastrous period for forest fires in Scotland often occurs in the month of June, and in the year 1920 no less than 5,698 acres of Scottish forests were destroyed by fire in this one month.

Any combination of climatic circumstances having the effect of desiccating the surface growth is to be regarded as potentially dangerous. The main factors in this respect are sunshine, wind, and prolonged frost, while the chief natural protective agency in all parts of the country is the moisture precipitated as rain or dew coupled with the capacity of the soil and herbage to retain moisture. Temperature plays a secondary but important role in forest protection. Hard frosts are factors of danger, while a mild and equable period during the early spring months will induce the early growth of grasses and weeds, the young and succulent shoots of which rapidly reduce the inflammability of the dead 'flag' of the previous year's growth.

In Great Britain the average annual rainfall varies much for so small a country, being highest along the western side of the Island. The amount of the annual precipitation is, however, nowhere spread evenly throughout the year and, in the wettest districts, periods of frost, drying wind, or summer heat are all that is needed to bring conditions in individual localities to the point of fire danger. Of course abnormal conditions occur from time to time. The hot summers of 1911, 1921, and 1929, to mention recent drought years only, were all also bad 'fire years'—circumstances in 1929 being aggravated by the severe frost of the early part of the year, which left all dead growth in a state of tinder. From the point of view of protection against forest fires, wet spring and summer seasons are godsends to the forester.

COMMON CAUSES OF FOREST FIRES.

Forest fires arise from natural causes or by act of man, and in the latter case may be brought about either by accident, stupidity, or wilfulness. The case for spontaneity, though frequently receiving notice, is actually a weak one. A combination of circumstances which will convert a casually dropped piece of glass into an effective burning-glass cannot be dismissed as impossible, but very few outbreaks of forest fire have yet been traced definitely to such cause. M. Lavauden of the Department of Eaux et Forêts records that he has experimented with innumerable pieces of glass of all shapes and colours under the most favourable of conditions, but has never succeeded in causing a fire by such means. Of the possible natural sources of fire origin, lightning is unquestionably to be regarded as dangerous, though less so in Britain—where thunderstorms are comparatively infrequent—than on the continent of Europe. An outbreak of fire in a compartment of five-year-old Scots pine at Redneck in Thetford Chase in East Anglia in July 1929, was, after careful investigation, attributed directly to a lightning flash by the local forest officers in charge. The soil at Redneck is almost a pure sand, and lightning statistics quoted by Schlich show that, in Lippe-Detmold, there is greater danger on sandy soils and loams than on clays and marls. Fortunately there is no question of volcanic agency in Britain, but that spontaneous combustion can occur subterraneously or in mining spoil-heaps in certain circumstances is not to be denied. An instance of this spontaneity under natural conditions is the phenomenon of the 'burning cliffs' (Liassic) of Lyme Regis and Charmouth. The bituminous Lias shales contain iron-pyrites, the decomposition of which has led, upon occasions, to spontaneous combustion.

Pure accidents that can result in forest fires are in considerable variety, but, in general, causes will be found to fall within one or another of the following categories:

Sparks from railway engines.
Sparks from road engines.
Fires originating from colliery or rubbish tips ('gob fires').
Fires started for their several purposes and with or without all reasonable precaution by farmers and graziers, foresters, gamekeepers, and timber merchants.
The dropping of lighted matches, cigarettes, or tobacco by smokers.
Fires lighted thoughtlessly by picnic parties and irresponsible persons.
Incendiarism.
Act of God, i.e. lightning, &c.

Fires resulting from military manœuvres can be classed as accidental, although they are usually caused by the fault of an individual. The burning out of wasps' nests is a common practice throughout the country and is a fruitful source of origin of surface fires on dry grass lands, among furze or whins and in hedgerows. Very little charcoal burning is now done in Great Britain and risks from this source are really negligible. Sportsmen's shot-guns

have been blamed and, where muzzle-loading sporting weapons, using rag or paper wadding, still linger, there may be some risk, but the manufactured wadding ejected from the modern breech-loader is, in this respect, entirely innocuous.

It is to be feared that a large proportion of the fires occurring in British forests arise from the stupidity of individuals. The smoker, whether he be the hunting man at the covert side, or the casual passer-by, is obviously a potential culprit; also the irresponsible lighter of fires by the wayside and elsewhere who obeys 'the prompting of the incendiary who lives in the heart of every man'. The starting of fire in dangerous places by farmers, foresters, or gamekeepers without proper precaution is gross and inexcusable carelessness, however legitimate and laudable their object may otherwise be, while bank holiday week-ends are a nightmare in populous or popular localities. Incendiary forest fires are, it is to be hoped, few and far between, but it must be recognized that criminal cases do occur. Wilful lighting of fire with intent to do damage in the forest should be punished heavily whenever the delinquents can be brought to book. Persons labouring under a sense of grievance, and the more unruly elements in the neighbourhood of extensive commons or populous centres, are sometimes so misguided as to resort to behaviour of this sort either out of pure mischief or worse, or as a counter-measure against an encroachment upon a fancied 'right'. The methods employed by such people to effect their purpose are often ingenious, and the catching of the wrong-doer *in flagrante delicto* is not generally easy. A good many of the suggested causes of forest fires can be dismissed as ridiculous—e.g. spontaneous combustion of the humus layer, chafing of one dry branch against another by wind, or even Hertzian waves! The electrical development now so extensively being undertaken in many parts of the world, including Great Britain, is, however, a source of danger through the possible breaking of insulators, or of the live cable itself, within the forest.

The causes of 504 separately investigated outbreaks of forest fire which have occurred in recent years in Great Britain[1] are classified in the following table:

Cause of Fire.	*No. of Fires.*	*Percentage of Total.*
General public	167	33·0
Railways	186	37·0
From adjacent lands	35	7·0
Road engines	30	6·0
Forest workers	25	4·9
Incendiarism	4	0·8
Burning of lop and top	3	0·6
Lightning	1	0·2
Unknown	53	10·5
Total Number of fires	504	100

It is seen that no fewer than 33 per cent. and 37 per cent. respectively were caused by negligence on the part of the public and by the railways, while in

[1] Forestry Commission Records (by permission).

10 per cent. of the cases the cause of the conflagration could not definitely be traced. The remaining hazards together accounted for only a bare 20 per cent. of the total number of fires. These figures are, of course, an indication only, and are insufficient to assess, with any degree of certainty, the relative degrees of danger.

FIRE PROTECTION

It is generally accepted that natural forest offers a greater resistance to damage from external causes (including fire) than do plantations artificially formed. State Forestry in Great Britain is, however, dealing with artificially formed forests and, regarded broadly, the most promising means of protection against fire lie in the direction of public education as to the value of forests to the nation, and the grave danger from fire to which they are subject. Half-hearted attempts of this nature have already been made, but to be effective the effort must be sustained and persistent. Broadcasting, the press, warning notices on the ground, in the newspapers, and at police and railway stations, and, possibly best of all, the childrens' schools, should each and all be made a medium of propaganda. Warning notices should be used plentifully. They ought to be striking in appearance, clearly printed in plain type, and framed rather as an order than as a request; the wording should be short and to the point, particular care being taken not to make the notice discursive, suggestive, or ambiguous in any way.

In all cases of fire trespass in which it becomes necessary to prosecute, action should be as speedy as possible and, where conviction is secured, the facts should be made public; the name and address of the offender in serious cases might, with effect, be 'gibbetted' after the manner of the Railway Companies in dealing with persons convicted of evading their fares. Publicity, properly exploited, can be made to prevent more fire losses than any other practicable form of forest protection from fire yet devised.

The conventional lay-out of the forest into compartments intersected by a system of fire traces and rides is universal. There is wide variation in practice as to the width of the fire traces, which should not gridiron the forest with mathematical regularity, but rather be laid down along the contours, crests, or ridges, at an angle inclined to the direction of the winds prevailing at the more dangerous seasons of the year and not always at right-angles thereto; rarely will the terrain be found to demand the setting out of a fire trace along a valley bottom and depression. Fire traces are useless unless kept bare of all inflammable weed-growth, bushes, and rubbish, and the cost of this work is heavy. Responsible writers are casting grave doubts upon the effective value of fire traces on the ground of cost of formation and maintenance alone, and one rather base motive adduced for the continuance of fire traces is that they can be cleared in order to impress the public that steps to combat fires are really being taken. It is to be recognized that, once a fire has taken serious hold, no fire trace ever made can be relied upon, with certainty, to stop its progress. Narrow fire lines will stop an ordinary fire when wind is light, but the widest

of fire traces will not arrest the progress of a fierce fire with a strong wind behind it; at the best they afford vantage points at which to attack or intercept the oncoming fire and can thus be made the means of saving adjacent compartments. All things considered, the science of forest fire-fighting will have to become a much more exact one before the fire trace can be abandoned as entirely useless. The efficiency of fire traces is enhanced if they are flanked by belts of the more fire-resistant species. The notion that non-inflammable trees and plants exist dies hard, but foresters are being bluntly reminded of the fallacy from several quarters. M. le Conservateur Anterriew-Vons, of the Department of Eaux et Forêts, at the World Forestry Congress held in Rome in 1926, said, 'Les histoires mirifiques de plantes ignifuges doivent être réléguees sans hésitation parmi les vieilles légendes', and it must be recognized that such a thing as a fire-proof plant does not, in fact, exist. The species usually recommended for the purpose in Britain are *Alnus incana*, *Robinia pseudacacia*, *Castanea vesca*, and *Populus alba*, all of which can be coppiced, while *Fagus sylvatica* will also answer the purpose, its dense canopy keeping the ground bare. A double row of Black Italian poplar can, where soil and terrain are suitable, be made to function as a spark arrester. The foregoing species are all mentioned with due regard to their practical limitations, and the choice of species for the formation of fire-resisting belts is, in any given case, to be dictated entirely by the local conditions of soil and climate.

Where a forest is traversed by a public road it is customary to leave a fire trace for protection on either side of the roadway. It is open to doubt if this is really a wise plan. If the plantings are carried close up to the roadside the considerable expense of keeping the unplanted strips bare of vegetation is avoided and the incidental risk of fire in the plantations is no greater; rather the reverse, in fact, for any extensions of the roadside waste, whether fenced or not, are direct invitations to picnic parties and other dangerous forms of trespass. To minimize the opportunities for trespassing where transverse fire lines and rides strike a public roadway, it is also advisable to carry the planting over the otherwise open ends to a depth from the road sufficient to mask the openings altogether. This gives an impression to wayfarers that the forest is solid and impenetrable. All except the main approaches to the forest can be closed in this way and the sealed exits can at any time be opened out at small cost if need arises.

The division of coniferous forests into felling series, by means of which the annual *coupes* are spread over the forest and large even-aged areas are avoided, tends to localize the fire hazard, and the early removal of lop and top from the felling areas, and litter from thinning operations, is to be advised.

Chemical weed-destroyers have not so far been found very successful as aids to the clearing of fire traces and rides. The cost of treatment with sodium chlorate, caustic soda, diluted sulphuric and hydrochloric acids, and other chemicals, including common salt, in sufficient strength to kill the vegetation outright, is heavy. Another difficulty is the obtaining of water conveniently in certain districts for dilution. Sodium chlorate has given the best results

to date; a 5 per cent. solution is recommended. Arsenical weed killers and other poisonous compounds and substances are too dangerous to animal life to be tolerated, as well as too expensive for practical purposes if utilized on a large scale. Short of removing the surface layer of the fire traces by 'screefing' or turning it in with the plough, both of which methods are effective within limits, it is usual to get rid of the surface vegetation by controlled burning. This burning is no use at all unless it is thorough, and it constitutes a grave menace to the safety of the forest unless it is properly carried out under skilled supervision. It is always to be remembered that wind will spring up mysteriously on the calmest days, and that the very act of burning can cause the movement of strong local currents of air, by reason of the rapid rise of the heated air above the blaze, and the simultaneous inrush of cold air below, to fill the vacuum. Air currents will in such circumstances be drawn in from all sides and will sometimes play surprising tricks with improperly controlled burning operations. It may here be mentioned that ordinary corrugated iron sheets fitted with two 9-inch iron spikes on the lower edge, with projections to enable them to be driven into the soil by the foot, and two handles on the upper edge, will be found helpful in assisting to keep controlled burning within bounds on fire traces. Screens made in this way are easy to transport, handle, and fix in position, and have the additional advantage of being cheap, durable, and simple to construct and use. The *petit feu* employed by French foresters is not suited to present circumstances in the British State forests. This is the burning of moderately sparse weed-growth within established plantations by means of a quick fire. The heat generated must not, of course, be enough to damage the crop, and a nice assessment of local conditions generally is required. The object is to get rid of the inflammable material on the ground, while there is still insufficient to be actually dangerous, that worse may not befall at a later period. A system of banks of earth, to be kept clear of weeds, along the lines of the main fire traces is strongly to be recommended where the terrain is flat or very gently undulating, and the soil light. These banks can be quite low and will be found surprisingly effective in staying the progress of outbreaks of moderate proportions. The main objection is one of cost, but where fire traces are being 'screefed' or ploughed, the expense of piling up sufficient of the sods on one side for this purpose need seldom prove prohibitive. A cardinal rule is to destroy all litter and rubbish within the compartment and on the fire traces and rides, and thus to prevent the accumulation of any easily ignited material.

Whatever means of protection may be suited to a particular forest it is most important that a proper protective organization be devised. Organized patrol is a *sine qua non*. It is to be assumed that the forest officer, the forester, and the patrol men (who should be picked men) will each be thoroughly acquainted with his area, and it is advisable that the chief patrol man, whether he be styled 'fire warden' or not, shall be invested with police powers as a special constable. Uniform is impressive, and where holiday makers congregate this is a factor not to be ignored; the *brassard* is an inexpensive substitute, but

it is observable only at close quarters and lacks the 'long range' effect of a full uniform. The psychological aspect of this matter is worth attention. False, or practice, alarms with a subsequent discussion thereon, are instructive but ought not to be indulged in too often; Aesop has warned us of the evil of crying 'wolf' too frequently. Foresters, foremen, and gangers ought all to be provided with whistles or horns on which to sound alarm.

Written fire-control plans, setting forth the essentials in the simplest possible language, illustrated by ordnance survey maps to the scale of 6 inches to the mile should be prepared. These will indicate the danger spots, the look-out stations, the system of fire traces, the strategical points, the position of water-courses and ponds (although water can seldom be brought in effective quantity to a forest fire), stores of tools and apparatus, and all other information of local importance. This plan should be studied at frequent intervals by all responsible for supervisory work in the forest, and a *modus operandi* thought out for coping with outbreak in any compartment of the forest. Junior forest officers, foresters, and fire guards should be examined from time to time and encouraged to memorize the detail of the fire-control plans of their beats, and of the forest as a whole, and a small scale map (on the 1-inch scale) can with advantage be exhibited prominently in the local office on which *inter alia* the sites of origin of all fires should be recorded by conspicuous red dots, a method which in course of time automatically establishes the actual points of greatest danger in the forest. The principal danger spots and the other details of importance are, by means of the small scale map, impressed pictorially on the mind. If every fire that occurs is made the subject of a written report recording all available data concerning its outbreak, course, and suppression, the salient points contained in these reports will, if compared and correlated for the forest as a whole, form the soundest possible basis on which to found (and from time to time to revise) the detail of the fire-control plan.

Man power and tools are the main requirements when once a fire is located, and means must be devised to ensure the concentration at the point of danger of the largest possible number of men, equipped with suitable tools, in the shortest possible time. This task presents a multitude of difficulties, including those of rapid transport, and, in support of the organized patrol, look-out stations at the high points are valuable, still more so if they are equipped with the telephone or some audible means of alarm, such as directional signalling. Maroons, flags, or the semaphore can be utilized, but wireless transmission of alarm has not yet reached a simple enough stage to be of practical use, nor are British forests yet so extensive as to warrant aeroplane patrol. There can be little doubt, in a large and valuable forest, of the wisdom of connecting all the main points or stations of the fire-control plan by telephone.

In the preparation of fire-protection plans for extensive areas of conifer forest in dry regions where seasonal risk is exceptionally heavy, the use of an observation (sausage) balloon, communicating with the local head-quarters by telephone, is a possible and certainly effective form of general look-out station.

The promotion of forest workers' holdings and the occupation of agricultural lands within the forest is well recognized as a further means of protection against fires, and the land settlement which is proceeding in British State forests is to be regarded as a most valuable adjunct to forest protection.

FIRE FIGHTING.

The time factor is the essence of successful protection against the spreading of forest fires. The alarm must be immediate and a sufficient force of men must be collected on the spot without an instant of avoidable delay. In dealing with fire in the forest the most experienced supervisory officer present takes charge and his directions are to be followed with all possible speed by his assistants. The tendency to panic in emergency may be regrettable, but it is a very human one, and it is for this reason that prior consideration of the local problem in all its aspects is so very desirable. If all forest officers and foresters know their ground and the layout of the forest intimately and the possible emergency has been considered in advance, there will be no real cause for flurry, and the fire will be attacked from the point or points at which it can most readily be stopped or turned to a less inflammable or less valuable part of the forest. It is generally safe to assume that water will not be available, if only by reason of the difficulty of bringing it in effective quantity to the seat of outbreak. Recourse, in the great majority of cases, must be had to other means. Chemical extinguishers of strictly limited capacity are easily transported, but as with water the trouble is a quantitive one. Foam, carbon tetrachloride, and soda-acid extinguishers have been tried, and of these the most useful is the soda-acid form which has been found definitely to stay the progress of surface fires if sprayed before them. The difficulty is to bring a large enough quantity to the spot and to spray on a sufficiently large scale. The concensus of opinion in continental forests seems to be that all engines and devices for the use of water or chemical extinguishing agents in cases of forest fire are ill reeds to lean upon.

Dealing firstly with the fighting of surface fires, the opening attack is generally the attempt to beat out the flames, for which purpose birch branches, well furnished with twigs and vigorously applied, are the best and most handy tools. They are light, effective, and easily renewed, and can be cut and distributed over the forest beforehand after the method adopted in Thetford Chase and certain others of the British State Forests for some years past. The birch branches so distributed should be renewed from time to time in order to ensure the provision of a supple weapon whenever emergency arises. Difficulties are experienced by fire fighters from smoke and heat, and at times frontal attack is rendered impossible from these causes. Beating-out along the flank of the fire then becomes necessary, and frequently this is the best means of narrowing the front or deflecting the progress of the fire altogether. Some adaptation of the military gas mask is possible as a means of protection against dense smoke, the effects of which are often painful, and in lieu of masks small towels wrung out in cold water are useful if lightly wrapped round the mouth

and nose. A supply of water in buckets must, of course, be available for the purpose. Hessian sheeting, which is obtainable in rolls of 50 feet each, has been tried. It can be laid flat on the track of the oncoming fire at a fast rate but has been found not sufficiently uninflammable in itself to serve its purpose, and to be useful some means of fire-proofing the material will have to be found. Where time and soil conditions permit a shallow trench can be dug to isolate the burning area, and if the soil be thrown out on the side from which danger threatens this is also helpful. Where the fire is out of control by other methods, or threatens a large or specially valuable area, counter firing will sometimes become advisable. Counter-firing is the deliberate burning of a strip of the forest directly in the route of the accidental fire which dies out for lack of fuel on reaching the purposely fired area. Counter-fires can be made to burn *towards* the original conflagration, and if this can be effected the two fires burn out on meeting one another. Counter-firing, or back-firing as it is sometimes called, is never to be undertaken lightly, and unless properly conceived and controlled it may be much more damaging than helpful. All the same it is a necessary and valuable measure at times, and one more often to be prescribed in cases of crown fire than surface fire. Counter-firing can usually be more safely employed at night than in the day time. It is well known to meteorologists that wind usually dies down about sunset to blow again in the early hours of the morning with its previous vigour. This lull is often the foresters' opportunity for a successful counter-firing operation.

Crown fires have not yet become a feature of danger in British forestry, although cases are not altogether unknown. The only possible methods of dealing successfully with this eventuality are the direct suppression of the conflagration by water or chemicals, by counter-firing, or by the somewhat analogous means of felling a strip of the forest to break the continuity of the canopy and thus check the progress of the fire.

Sub-surface fires are extremely difficult to deal with. They usually burn themselves out or smoulder on until rain falls in sufficient quantity to saturate the ground. This type of fire is nearly always strictly local and needs to be continually watched until finally extinguished. In serious cases trenching is the safest, and really the only check. Underground fires are only to be feared in peaty or dry humus conditions and in exceptionally dry circumstances, but when once fairly alight they have been known, where conditions are favourable, to burn for months.

All forest fires require to be watched with the utmost vigilance by night as well as by day until all burning has ceased beyond a doubt over the entire field of the fire. Fires have an uncanny way of flaring up again in unsuspected spots, and any change in the direction or force of the wind may result in further outbreaks.

It is not to be denied that fire fighting in the forest, as elsewhere, is fraught with danger. In a recent forest fire the progress of the flames was so rapid that a workman was obliged to take refuge in a convenient ditch and allow the fire to pass over him (Margam, 1929). In another instance the fire advanced

so quickly that the workmen engaged in a frontal attempt to beat it out were forced to run to escape being enveloped (Wangford, Thetford Chase, 1929).

The tools to be provided for fire fighting are:

Grubbing hoes.	Axes.
Mattocks.	Bill hooks.
Iron rakes.	Heather burners' torches.
Four-pronged forks.	Chemical extincteurs.[1]
Spades.	First Aid Outfit.

Birch boughs or light besoms.

The long-handled multi-purpose spade, beloved of generations of agricultural workers in Devonshire, is a tool worthy of a wider distribution for the purpose of forest fire fighting. It can be made to move as much material in a given time as the ordinary type of spade and is much more adapted for use as a beater.

To sum up it can be stated confidently that, in common with so many others of the forester's operations, the technique of fire fighting in the forest cannot be reduced to rule of thumb. There can be no rigidity of outlook. Each forest presents its own peculiar fire problems and dangers, and each outbreak of fire its special difficulties, and it will not be out of place to repeat that the only real safeguard lies in the direction of care and organization. Care implies that the number of outbreaks will be reduced to a minimum, and organization that fires, when they do occur, will be attacked with speed, intelligence, and determination.

LEGAL ASPECTS.

Wilful destruction of forests by incendiary burning—arson is a crime unlikely to be encountered in forestry—is a felony. Section 16 of the Larceny Act, 1861, provides, *inter alia*, a maximum penalty of fourteen years penal servitude for the unlawful and malicious setting on fire of any part of any wood, coppice, or plantation of trees, or any heath, gorse, furze, or fern wheresoever the same may be growing. For any attempt to commit the offence under the Section the maximum penalty is seven years penal servitude. Growing trees, shrubs, underwood, plants, &c., are also protected from unlawful and malicious damage by the provisions of the Malicious Damage Act, 1861.

Common lands are, from various causes, particularly susceptible of being set alight, and the fire hazard in the case of forest lands in the close neighbourhood of commons is considerably aggravated by this proximity. The Law of Property Act, 1925, enacts that 'rights of access to commons shall not include any right . . . to light any fire thereon' (Section 193), and that any person who, without authority, lights any fire thereon is liable, on summary conviction, to a fine of forty shillings for each offence. This Act extends to England and Wales only.

[1] Chemical extincteurs are included because, whatever view may be held concerning the use of chemical extinguishers on a large scale, they are of real value in the suppression of small outbreaks.

Except in certain special cases which are referred to later, the burning of forests from accidental causes is, even where no negligence can be adduced, a legal tort for which action lies at Common Law. The doctrine involved is that of the law of dangerous things. Such dangerous things must be inherently dangerous, e.g. fire, explosives, water, ferocious animals, &c., and are (with certain well-recognized exceptions) kept at the peril of their owners so far as other people are concerned.

The cases specially excepted are:

1. Act of God.
2. Voluntary submission to risk.
3. Fault of plaintiff.
4. Independent act of a third party, e.g. a trespasser.
5. Where statutory authority to keep a dangerous thing is involved.

A fruitful cause of forest fires in Britain is the emission of sparks or the dropping of burning ashes by road locomotives, but in proceedings for the recovery of compensation for consequential damage it is immaterial what degree of care was exercised by the owners or drivers of the vehicles as they are covered by none of these exceptions.

In law the Railways stand in a category of their own. They are authorized to keep a dangerous thing and are protected, to a very considerable extent, by statute. There is no need to dilate upon the obvious risks of fire in which forests traversed or bounded by railway lines are placed, and the risks are greatly enhanced where the gradients of the lines are at all steep. The Railway Fires Act, 1905, and the Railway Fires Act (1905) Amendment Act, 1923, limit the amount of the compensation for loss to be paid by the Railway Company arising from any one fire resulting from sparks or cinders from a railway engine, to the sum of £200—under the earlier Act the amount was £100 only—and provides that notice, in writing, of the fire and of the intention to claim, must be given within seven days. Particulars, in writing, of the damage suffered, in which the amount of the claim in money must be stated, are to be lodged within twenty-one days of the date of the fire. This Act was not made retrospective. In those cases in which the damage suffered exceeds the statutory limit under the Railway Fires Acts, larger sums can be recovered where the plaintiff can give proof of actual negligence on the part of a Railway Company.

The only Act of Parliament framed for the specific purpose of regulating the burning of lands which may be afforestable, is the Heather Burning (Scotland) Act, 1926. This measure was, of course, enacted primarily in the interests of graziers and sportsmen, and not of those of foresters, but the regulations imposed are of use inasmuch as they put periods to the danger of the spreading of fire from moor to forest.

Section 1 provides that burning must be before the 16th April or after the 30th September in any year, with the modifications (*a*) that the proprietor, or tenant with the written authority of the proprietor, may burn from the

16th to the 30th April, both dates inclusive, and (*b*) that the tenant may, by the sanction of the Board of Agriculture for Scotland, burn up to the 30th April without the consent of proprietor. Deer forests, situated above the 1,500 feet contour, may be burned up to the 15th May. Burning in contravention of the provisions of the Act is an offence, and as its title implies, the Act applies to Scotland only.

INSURANCE.

The insurance of woods and plantations against fire risks is by no means the rule in Britain. British Insurance Companies will afford this form of assurance at premiums varying between 5*s*. 6*d*. and 15*s*. per cent. with 10*s*. 6*d*. per cent. as a reasonable mean. The differences in the rates of premium are due to the individual Insurance Companies, to special risks, such as proximity to roads or railways, and to the great variations in the actual terms of the policies, some being subject to average, some including the whole of the woods on an estate, and some only the young plantations.

A leading British Insurance Company quotes a rate of 10*s*. 6*d*. per cent., subject to average. In considering a proposal to insure woodlands they would require to know: (*a*) if the woods are near a railway and if so the actual distance; (*b*) if any sawing by power is done in or near the woods; (*c*) if the woods are open and accessible to the public; (*d*) if there is much undergrowth; and (*e*) on what basis the amount of the insurance is arrived at.

To be fully effective schemes of insurance should be founded on a complete schedule and valuation of the woods, each separate area being subject to average. The valuation must be reviewed at suitable intervals to allow for increment and, if the policy is renewed each year, adjustments can be made without difficulty.

Quite recently special consideration has been given to the question of the insurance of woodlands in Scotland by those Insurance Companies which are also Members of the Scottish Fire Offices Committee. The tariff adopted provides for a normal rate of 5*s*. per cent. if the growing timber is under forty years old, 4*s*. per cent. if the growing timber is forty years old or over, and additional rates (which may be modified where the plantation is forty years old or over) are chargeable in respect of proximity to a railway or public road and of area. An additional rate will also be imposed where felling is not done by estate employees. The Insurance Companies require a warranty that persons under the control of the insured shall be forbidden to light fires, for any purpose, in the woods or in the open within 100 yards thereof, each item of insurance is separately subject to average. The scheme is not, of course, all it would appear from the rates per cent. quoted, but it represents a very considerable step in the right direction.

The insurance of forest crops has received considerable attention abroad both through the Insurance Companies and through Mutual Societies which have been formed in France, Belgium, Holland, Finland, Norway, and elsewhere. This form of assurance appears to have functioned most successfully

in Norway where a mutual society for insurance against forest fires was launched in 1912 and has made rapid strides. The business increased from 1,200 policies in 1912 to 9,000 policies in 1913. The society pursues a double aim and seeks not only to cover the fire losses but to minimize the risks, notably by the maintenance of look-out stations and alarms. In Holland there are two mutual societies, one dating from 1894, but in 1926 only some 8 per cent. of the Dutch forests were insured.

It is surprising that fire insurance has not a greater vogue in forestry. It is the most efficient and obvious method of safe-guarding the interests of forest owners, and the spread of such insurance would also have the indirect effect of disclosing to members of the public that a forest is an insurable subject, in other words, it has a commercial value and is consequently entitled to the protection of the Law. Continental foresters have for some years past been giving attention to the possibilities of State action (compulsory and other) as being the least costly method of securing the general insurance of forests against destruction by fire and, in heavily forested countries, a scheme of State Insurance against fire would seem to be the inevitable outcome of these deliberations.

THE DIFFERENTIAL SHRINKAGE OF WOOD

BY S. H. CLARKE

Forest Products Research Laboratory

INTRODUCTION.

THE wood of a freshly felled tree contains moisture in two distinct forms. Part of it, in the form of absorbed or cell-wall moisture, is contained in the substance of the wood itself; the remainder, in the form of free moisture, occupies the cell-cavities and intercellular spaces of the wood. As a piece of wood dries, the free moisture is first evaporated; when this has all been lost the wood is said to have reached 'fibre saturation point'. In this condition the cavities of the wood contain only air, while the wood substance is still completely saturated. The loss of the free moisture is not as a rule accompanied by any change in the volume of the wood, but as drying proceeds beyond fibre-saturation point the cell-walls contract and shrinkage of the wood as a whole occurs (6). Other things being equal, the change in volume due to the shrinkage is roughly proportional to the specific gravity of the wood; that is to say, in two samples of wood of similar structure, the denser sample will usually undergo a greater change in volume than the less dense, under the same conditions. The differences in the structure of different species, however, affect the course of shrinkage to such an extent that this rule does not often hold in actual practice.

One of the outstanding peculiarities of wood is the fact that the linear shrinkage in passing from saturation to dryness differs considerably in the longitudinal, radial, and tangential directions. While, in the commoner woods, longitudinal shrinkage is so small that for general purposes it may be disregarded, the radial shrinkage in reaching the oven-dry condition is usually between about 2 and 8·5 per cent. of the initial, or saturated dimensions, and the tangential between about 4·2 and 14 per cent. (3). Although a study of the anatomical structure of the wood helps to explain the differences between radial and tangential shrinkage, the minute longitudinal shrinkage can only be explained by reference to the ultramicroscopic structure of the cell-wall. Recent X-ray examinations of fibres (5) have supported this view.

Several reasons have been suggested for the difference between radial and tangential shrinkage. It is generally accepted that the medullary rays, with the long axes of their cells in a radial direction, exercise a restraining influence on the radial shrinkage. Wagner (7) states that in the radial direction the fibres tend to shrink as much again as the rays. Furthermore, in many woods, bands of dense tissue running in a tangential direction alternate with bands of lighter and more porous tissue; elm (*Ulmus* spp.) is an example of this. When this arrangement is present, it is supposed to be partly responsible for the greater shrinkage in the tangential direction.

Forsaith (2), in writing of the timbers of New York State, deals with the relation of shrinkage to the anatomy of wood. He states that the higher the specific gravity of the wood the less is the difference between radial and tangential shrinkage; that, on the average, tangential shrinkage is about twice as great as radial shrinkage; and that tangential shrinkage is nearly constant, irrespective of weight.

Roth (4) describes the behaviour in drying of a small piece of fibre: 'its wall grows thinner, . . . its width, the thickness [diameter] of the fibre, becomes smaller, and the cavity or opening larger.' 'In a similar piece of fibre with a thinner wall, . . . the effect is the same, but the wall being only half as thick, the total change is only about half as great.'

The present investigation, which deals with the differential shrinkage of wood in the radial and tangential directions, was undertaken in order to examine these general statements, and to extend the observations. Some of the questions prompting the inquiry were:

(*a*) To what extent may specific gravity be regarded as an index of volumetric shrinkage?

(*b*) What relation exists between radial and tangential shrinkage? Is either more nearly constant, or more closely dependent on specific gravity?

(*c*) What is the effect of the medullary rays on shrinkage?

(*d*) How do the individual elements and tissues behave when wood shrinks?

(*e*) Do thin sections behave similarly to the blocks of wood from which they are cut?

MATERIAL AND METHODS.

Two hundred sample blocks, representing sixty species of twenty-three families of hardwoods, were taken from the wood collection of the Imperial Forestry Institute, Oxford. The specimens were selected to cover a wide range of structure, from a ring-porous wood with large rays (e.g., *Quercus alba* L., white oak) to a very fine-textured wood (e.g., *Buxus sempervirens* L., box); and from a very light wood (e.g., *Erythrina stricta* Roxb., air-dry specific gravity 0·29) to one that sinks in water (e.g., *Casuarina torulosa* Dryand, Australian She-oak, air-dry specific gravity 1·03). Special attention was given to the size of the medullary rays, and many of the woods were chosen with reference to this feature.

The sample blocks were cut so that on the transverse surface the growth-rings were parallel to one edge. As nearly as possible the blocks were 15 to 25 mm., square, this being governed largely by the size of the specimen available; the thickness was limited to about 5 mm., in order to minimize the chances of case-hardening. The blocks were carefully squared, and smoothed with fine glass paper. They were weighed to the nearest 0·001 gm., and the dimensions measured to 0·01 mm., by means of a micrometer gauge, the blocks being marked with Indian ink to ensure that subsequent measurements were made

along the same lines. The specific gravity was calculated from the ratio $\frac{\text{air-dry weight}}{\text{air-dry volume}}$. It is realized that the most reliable figures for specific gravity are probably yielded by the ratio $\frac{\text{oven-dry weight}}{\text{saturated volume}}$, but in the case of the thin blocks used in this experiment it was found that a serious error was introduced in the measurement of the longitudinal dimensions, because when the blocks were saturated in water the broken ends of the fibres straightened out and made the transverse surfaces very rough. The blocks were saturated in water in a glass vessel from which the air was exhausted. In order to ensure uniformity of treatment the saturated blocks were all dried together; first, they were exposed to the air on a shelf in the laboratory until they were air-dry, then they were placed in an oven at 60° C. for three days, and, finally, in another oven at 100° C. until they reached constant weight. The radial and tangential dimensions of each block were measured in the saturated and oven-dry conditions.

In order to compare the behaviour of thin sections with that of solid blocks, transverse sections (12–16 μ) were cut from certain blocks which had been previously softened by boiling in water. The sections were mounted in water, and their dimensions measured by projecting an image at a magnification of thirty diameters on to a screen. The saturated sections were then gently heated over a spirit lamp; in this way the free moisture was driven off, and the section dried and contracted. As soon as the contraction was observed to be complete, a drop of Canada balsam was placed on the section, and this was covered by a dry coverslip. The image of the dry section was then measured so that the amount of shrinkage could be estimated.

EXPERIMENTS AND RESULTS.

(*a*) *Shrinkage of small samples.*

Two or more blocks were taken from each of seventy-nine specimens, and their saturated and oven-dry dimensions were measured. In Table 1 the shrinkage is expressed as a percentage of the saturated dimensions, each number being the average of at least two results. Owing to considerations of space the complete list is not given, but the examples selected illustrate the full range of behaviour.

Table 1 shows that radial shrinkage ranged from 1·29 to 6·75 per cent. of the saturated dimensions, tangential shrinkage from 5·02 to 13·30 per cent., and the ratio $\frac{\text{tangential shrinkage}}{\text{radial shrinkage}}$ 1·1 : 1 and 7·9 : 1 (throughout this paper the ratio will be briefly termed the ratio T/R). It is possible to select pairs of specimens with about the same specific gravity but very different in other properties. For instance, the specific gravities of *Faurea* sp. and *Quercus ilex* L. were 0·72 and 0·70 respectively, while the radial shrinkages were 1·29 and 4·58 per cent., the tangential 5·48 and 8·35 per cent., and the ratio T/R 4·2 : 1 and 1·8 : 1 respectively. The behaviour of the three species of *Casuarina*

TABLE I. *Specific Gravity and Shrinkage of Typical Samples.*

Family.	*Species.*	*Specific gravity (air-dry).*	*Shrinkage from saturated to oven-dry condition.*		
			Radial (R) (% of saturated dimensions).	*Tangential (T) (% of saturated dimensions).*	*Ratio T/R (R = 1).*
Bombacaceae	*Durio zibethinus* Murr.	0·47	2·67	5·34	2·0
Buxaceae	*Buxus sempervirens* L. (Boxwood)	0·93	6·75*	9·91	1·5
Casuarinaceae	*Casuarina equisetifolia* L. (She oak)	0·97	6·23	12·54	2·1
,,	,, ,, ,,	1·00	4·40	10·39	2·9
,,	*Casuarina torulosa* Dryand (She oak)	1·03*	2·06	9·51	5·0
Ebenaceae	*Diospyros virginiana* L. (Persimmon)	0·84	6·15	10·91	1·8
Fagaceae	*Quercus alba* L. (White oak)	0·66	5·22	9·66	1·8
,,	*Quercus ilex* L. (Holm oak)	0·70	4·58	8·35	1·8
,,	,, ,, ,,	0·71	3·15	9·51	3·1
Leguminosae	*Erythrina stricta* Roxb.	0·29†	1·90	6·31	3·3
,,	,, ,, ,,	0·34	2·16	5·04	2·3
Meliaceae	*Swietenia macrophylla* King (Mahogany)	0·56	4·34	5·49	1·3
,,	*Swietenia* sp. (Mahogany)	0·52	4·48	5·02†	1·1†
Moraceae	*Chlorophora excelsa* Benth. and Hook	0·68	3·19	5·26	1·6
,,	*Ficus* sp.	0·37	3·44	6·43	1·9
Myrsinaceae	*Myrsine melanophleos* R. Br.	0·73	2·32	13·30*	5·8
,,	*Rapanea rhododendroides* Mez.	0·84	5·61	12·93	2·3
Platanaceae	*Platanus occidentalis* L. (Plane)	0·54	5·36	9·52	1·8
,,	,, ,, ,,	0·75	5·30	12·68	2·4
,,	,, ,, ,,	0·57	5·82	11·24	1·9
,,	*Platanus orientalis* L. (Plane)	0·60	2·80	9·47	3·4
Proteaceae	*Cardwellia sublimis* F. Muell. (Silky oak)	0·56	2·40	9·32	3·9
,,	,, ,, ,,	0·60	3·49	10·71	3·1
,,	*Faurea* sp.	0·72	1·29†	5·48	4·2
,,	,,	0·75	1·41	6·80	4·8
Rhizophoraceae	*Carallia calycina* Benth.	0·90	2·82	10·70	3·8
,,	*Carallia integerrima* DC.	0·78	1·62	12·87	7·9*
,,	*Carallia lanceaefolia* Roxb.	0·70	2·37	9·27	3·9
Rubiaceae	*Gardenia coronaria* Buch-Ham. (Siamese boxwood)	0·81	2·47	6·51	2·6
Salicaceae	*Populus nigra* L. (Poplar)	0·55	5·46	10·45	1·9
,,	*Salix coerulea* Smith (Willow)	0·41	2·64	8·16	3·1
Ulmaceae	*Ulmus major* Smith (Dutch elm)	0·55	5·35	8·29	1·5
,,	*Ulmus montana* Stokes (Wych elm)	0·65	4·95	10·40	2·1

* Maximum value of samples examined. † Minimum value of samples examined.

is also interesting in this respect; while their specific gravities were very similar, their radial shrinkages were 6·23, 4·40, and 2·06 per cent., their tangential shrinkages 12·54, 10·39, and 9·51 per cent., and the ratio T/R 2·1, 2·9, and 5·0.

Thus, the table shows that with a wide selection of woods neither radial nor tangential shrinkage is constant, nor is the ratio T/R; and that even in closely allied species there may be no close relation between specific gravity and any of these characteristics. It cannot be stated as a rule that woods with large rays show less radial shrinkage than woods with small rays; the former, however, frequently show a greater tangential shrinkage than the latter.

A more detailed study of the variation of shrinkage within a genus was carried out on *Ulmus major* Smith and *Ulmus montana* Stokes. Twenty-five small blocks were treated in the manner described above, and typical results are shown in Table 2.

TABLE 2.

Ulmus spp.: *Shrinkage and Specific Gravity.*

Species.	*Specific gravity (air-dry).*	*Shrinkage from saturated to oven-dry condition.*		
		Radial (R) (% of saturated dimensions).	*Tangential (T) (% of saturated dimensions).*	*Ratio T/R (R = 1).*
Ulmus major (Tree 1)	0·61	6·4	9·5	1·5
	0·59	5·9	8·6	1·4
	0·57	6·0	9·2	1·5
	0·56	5·7	8·7	1·5
	0·54	5·5	8·6	1·6
	0·52	4·9	8·0	1·6
Ulmus major (Tree 2)	0·60	6·0	9·1	1·5
	0·58	6·0	9·4	1·6
	0·57	5·6	8·4	1·5
	0·55	5·2	8·9	1·7
	0·48	4·3	7·3	1·7
	0·48	4·2	6·4	1·5
Ulmus montana	0·71	4·8	10·6	2·2
	0·66	5·6	10·9	2·0
	0·65	4·7	10·5	2·1
	0·63	5·0	9·8	2·0
	0·63	4·7	10·3	2·2
	0·61	4·9	9·9	2·0

The material of *Ulmus major* behaved differently from that of *Ulmus montana*. The specific gravity and ratio T/R are both greater in the latter, while on the whole the radial shrinkage is greater in the former. This means that even in closely related species the difference between radial and tangential shrinkage is not necessarily inversely proportional to specific gravity.

(b) Shrinkage and specific gravity.

The degree of correlation between specific gravity and the different types of shrinkage was expressed mathematically by means of correlation coefficients (8). The correlation coefficient always lies between +1·0 and −1·0. If two variables are directly and absolutely proportional the coefficient is +1·0; if they are inversely and absolutely proportional the coefficient is −1·0. If there is no relation between the variables the coefficient is 0·0. Any intermediate values indicate imperfect correlation. The probable error is a check on the significance of the coefficient of correlation and indicates errors that may have been introduced by random sampling. Provided that the probable error is small, a correlation coefficient of about 0·4 indicates that a definite, though not close, relation exists; if the coefficient is in the neighbourhood of 0·7 the relation may be regarded as close.

In order to investigate the relation between specific gravity and shrinkage within a single species, figures obtained during the examination of two trees of *Ulmus campestris* L. (1) were compared. The results quoted by Koehler and Thelen (3) for some of the more important woods of the United States were used in studying the relation within a group of different species. The correlation coefficients obtained from these data are given in Table 3.

Table 3.

Correlation between Specific Gravity and Shrinkage.

Correlation coefficient between specific gravity and	*Source of Data.*		
	U. campestris. Tree 1.	*U. campestris.* Tree 2.	*Koehler and Thelen.* (Hardwoods.)
(*a*) Volumetric shrinkage .	+0·667±0·051	+0·307±0·118	+0·511±0·064
(*b*) Radial shrinkage . .	+0·745±0·041	+0·467±0·101	+0·589±0·057
(*c*) Tangential shrinkage .	+0·440±0·074	+0·102±0·128	+0·561±0·060
(*d*) Ratio T/R. . .	−0·403±0·077	−0·281±0·120	−0·285±0·080

In the woods studied, specific gravity was fairly closely related to volumetric shrinkage, but more closely to radial shrinkage. It was definitely, but not closely, connected with tangential shrinkage. The negative coefficients show specific gravity to be inversely, but not closely, related to the ratio T/R. This means that there is a tendency for the difference between radial and tangential shrinkage to be less in the heavier woods.

The degree of relation between the proportion of fibres present and the different types of shrinkage in *Ulmus campestris* was found to be of the same order as that given above for specific gravity.

The species treated by Koehler and Thelen did not, however, include many with prominent rays, and the results given in Table 1 suggest that the connexion between specific gravity and shrinkage might be different in woods

with large rays. Accordingly correlation coefficients were calculated from the data obtained during the present investigation, with the following results:

Specific gravity and radial shrinkage $+0{\cdot}255 \pm 0{\cdot}075$
Specific gravity and tangential shrinkage $+0{\cdot}554 \pm 0{\cdot}056$

In woods with large rays, therefore, the order appears to be reversed, specific gravity being more closely connected with tangential shrinkage than with radial.

(c) Shrinkage of medullary rays.

Several large compound rays were dissected out from blocks of wood, saturated in water, and measured under the microscope, using a mechanical stage and a hair-line eyepiece. They were allowed to become air-dry, and after being oven-dried at 100° C. they were remeasured. The longitudinal shrinkage of the rays (as a percentage of the saturated dimensions) was:

Cardwellia sublimis F. Muell., 1·67, 1·3;
Helicia terminalis Kurz., 1·43;
Piper elongatum Jahl., 1·65, 2·79;
Quercus ilex L., 2·5, 2·41, 3·21, 3·31.

The shrinkage in height was:

Cardwellia sublimis, 4·35, 3·39;
Piper elongatum, 5·97;
Quercus ilex, 3·1, 4·2, 7·9.

The longitudinal shrinkage of the rays is less than the radial shrinkage of the wood as a whole; but the shrinkage of the rays in height is many times greater than the longitudinal shrinkage of the wood as a whole.

(d) Shrinkage of thin sections.

The shrinkage of a number of thin transverse sections was determined by the method described (p. 95), the shrinkage of the blocks from which they were cut having been determined previously. Typical results are given in Table 4.

TABLE 4.

Comparison of Thin Sections with Blocks of Wood.

Species and sample number.		*Radial shrinkage (R).*		*Tangential shrinkage (T).*		*Ratio T/R.*	
		Section.	*Block.*	*Section.*	*Block.*	*Section.*	*Block.*
Ulmus major	1	7·5	6·4	12·7	9·5	1·7	1·5
	2	5·9	6·0	9·4	9·2	1·6	1·5
	3	4·9	4·3	7·5	7·3	1·5	1·7
Ulmus montana	1	6·6	4·8	12·7	10·6	1·9	2·2
	2	6·6	5·6	11·7	10·9	1·8	2·0
	3	5·0	4·7	11·0	10·5	2·2	2·1

With one slight exception, the shrinkage of the section is greater than that of the block. This is attributed to the treatment, in that, firstly, it was only to be expected that a thin section would dry more evenly than a block, and that there would be fewer internal stresses; and, secondly, the sections were thoroughly dried and fixed in the dry condition in a way which was impracticable for the blocks.

The comparison of thin sections with the blocks of wood from which they were cut was pursued further by observing the behaviour of a single vessel in the drying of a piece of wood and of three successive transverse sections. The changes undergone were very similar, but the results were not absolutely conclusive, owing to the difficulty of measuring accurately the vessels in a block of saturated wood. Taking all these facts into consideration, however, there is good reason to believe that the changes in the dimensions of a thin section are similar to, if not the same as, those which would occur in a block of wood dried slowly so as to minimize drying stresses.

(*e*) *Shrinkage of individual elements.*

The behaviour of individual elements was observed in thin sections of wood.

Vessels. Forty-nine vessels of eleven species were examined. In the majority of cases (thirty-four) as the section dried the tangential diameter of the vessel lumen decreased and the radial diameter increased slightly. Twelve vessels conformed to this rule except that one or the other diameter showed no measurable change; only three vessels were observed to behave in a contrary manner. Fig. 1 *b* is a *camera lucida* drawing of three vessels of *Grevillea robusta* Cunn., in a saturated condition; Fig. 1 *a* shows the same vessels in a dry condition, and illustrates the change described. The two figures may easily be compared by superimposition. In most of the vessels the cross sectional area of the lumen decreased slightly in drying, but in some a slight increase was noted. It appeared probable that the change in the lumen depended upon the surrounding elements.

As a matter of interest, special attention was given to *Diospyros virginiana* L., the vessels of which have unusually thick walls. In most cases the diameters of the lumen behaved in accordance with the rule just stated, namely, that the tangential diameter decreased and the radial diameter increased, while in every case both external diameters decreased as the section dried.

Fibres. Fibres of the following species were examined in the saturated and dry conditions: *Bursera serrata* Wall., *Buxus sempervirens* L., *Grevillea robusta* Cunn., *Platanus occidentalis* L., and *Platanus orientalis* L. In every case the external diameters of the fibre decreased on drying, and in practically every case the diameter of the lumen increased. Fig. 2 *b* shows a portion of a saturated transverse section of *Grevillea robusta*, with a group of fibres (*f.*); this may be compared with Fig. 2 *a*, which shows the same elements after the section had been dried. The fibres behaved in the manner described.

Wood parenchyma. Figs. 2 *a* and *b* also illustrate the changes that occur in the wood parenchyma (*w.p.*) of *Grevillea robusta* as the wood dries. The cells

are shortened tangentially, but often increase in the radial dimensions in the same way as the vessels.

Medullary rays. When a medullary ray is separated from the rest of the wood it shrinks considerably in height (p. 99); this suggests that there is a strain between fibres and rays in a radial plane. Actually it was found that in tangential sections the rays showed practically no change in height on drying, but decreased in width. This change is reflected in the behaviour of the individual cells (compare Figs. 4 *a* and *b*).

Figs. 3 *a* and *b* illustrate the behaviour of certain tissues in a sample of *Ulmus montana*. Fig. 3 *a* represents a transverse section in the dry and Fig. 3 *b* in the saturated condition. The shaded areas represent groups of fibres, and the unshaded parts represent the alternating bands of vessels, the medullary rays, and a small amount of wood parenchyma. In every case the groups of fibres have decreased both radially and tangentially on drying; the groups of vessels with their vasicentric parenchyma have decreased tangentially to the same extent as the fibres, but there is little or no change in the radial dimensions.

DISCUSSION OF RESULTS.

The differential shrinkage of wood appears to be due fundamentally to three causes: firstly, to the peculiar molecular arrangement of the constituents of the cell-wall; secondly, to the fact that the composition of thick cell-walls is not homogeneous; and, thirdly, to the shape and arrangement of the cells. The effect of the first factor is seen in the small amount of shrinkage exhibited by elements in the direction of their long axis. The effect of the second factor is illustrated by the shrinkage of the fibres (Figs. 2 *a* and *b*); if the composition of the fibre-walls were uniform it would be expected that on shrinking the cross-section of the lumen would decrease in the same proportion as the cross-section of the fibre. Actually, the area of the lumen increases, indicating that *the inner layers of the fibre-wall shrink to a greater extent than the outer layers, while the overall shrinkage of the fibre-groups is controlled by the outer layers of the fibre-wall.* As a result of the third factor (the shape and arrangement of the cells), the shrinkage of a piece of wood in drying varies from point to point in the wood, each type of element behaving in a different but characteristic manner. It is known that the medullary rays tend to check the radial shrinkage, and that this is almost certainly due to the ray-cells having their longest axis in a radial direction. The behaviour of the medullary rays appears to be the primary cause of differential shrinkage in a transverse plane. Of the longitudinal elements the fibres seem to play the most important part, and this is natural in view of the fact that they usually contain most of the wood substance. In this investigation the fibres were the only elements that did not undergo considerable deformation in shrinkage owing to the influence of neighbouring tissues, but they were responsible for the deformation of the vessels and of the ray and wood parenchyma cells. As a general rule the vessels and wood parenchyma cells were slightly compressed tangentially, and

extended radially as shrinkage took place. In this way the effect of the radial shrinkage of neighbouring fibre-groups was considerably reduced, the wood as a whole shrinking much less than the fibres in the radial direction.

Thus the amount and form of the overall shrinkage of a wooden block depends not only on the amount and composition of the wood substance present but also on its distribution, a characteristic not easily expressed in mathematical terms. Although correlation coefficients indicate a definite relation between volumetric, radial, and tangential shrinkage, on the one hand, and specific gravity, on the other, the relation is not always close. The reason for this is, doubtless, the variation in the composition and distribution of the wood substance.

Both radial and tangential shrinkage vary within wide limits, and the connexion between either and specific gravity also varies. In the material of *Ulmus campestris* both specific gravity and the proportion of fibres in the wood were more closely parallel to radial than to tangential shrinkage. In the group of species treated by Koehler and Thelen, specific gravity appeared to be about equally close in its connexion with radial and tangential shrinkage. In the group of species examined in the present investigation, however, specific gravity was more closely parallel to tangential than to radial shrinkage. These observations suggest that specific gravity should not be regarded as a reliable index of radial, tangential, or, incidentally, of volumetric shrinkage, when considering the wood of a large group of species of different structure. It is possible, however, that within a single species specific gravity may be a more reliable index of these factors.

An attempt was made to recognize characteristic types of tissue distribution accompanying particular types of shrinkage in the species examined. This was not easy, owing to the wide range of structure shown, and the examples given will need confirmation as opportunity arises. Of the woods investigated, the radial shrinkage most nearly approaches the tangential in mahogany (*Swietenia* spp.); the rays of this wood bend round the vessels and their cells have thin walls; the fibres show a fairly regular radial arrangement, and the wood parenchyma, which is arranged in narrow terminal bands, is relatively sparse. In other woods it was found that the presence of large rays is frequently accompanied by a high tangential shrinkage.

SUMMARY.

1. The overall shrinkage of a block of wood with loss of moisture is the resultant of the several different types of behaviour shown by the individual elements.

(*a*) The *fibres* alone appear to shrink regularly in both radial and tangential directions, and are not distorted by neighbouring elements.

(*b*) The *medullary* rays restrict the radial shrinkage of the wood as a whole, while the shrinkage in height of the rays is practically inhibited by the fibres; as a result of the opposing forces the ray-cells become narrower tangentially but alter very little in height.

(*c*) The *vessels* and *wood parenchyma* cells generally become narrower tangentially but wider radially.

2. In the wood of *Ulmus campestris*, specific gravity was much more closely connected with radial than with tangential shrinkage, and it was fairly closely related to volumetric shrinkage. While it is possible that the same rule may hold for other species, it cannot be extended to include any group of species of differing structure.

3. With the samples investigated, radial shrinkage was found to vary between 1·29 and 6·75 per cent. of the saturated dimensions, tangential shrinkage between 5·02 and 13·30, and the ratio $\frac{\text{tangential shrinkage}}{\text{radial shrinkage}}$ between 1·1 and 7·9 per cent.

4. The high ratio $\frac{\text{tangential shrinkage}}{\text{radial shrinkage}}$ in many woods with large rays is due rather to a high tangential shrinkage than to a low radial shrinkage.

5. Thin transverse sections were found to behave similarly to the blocks of wood from which they were cut.

ACKNOWLEDGEMENTS.

I wish to express my indebtedness to Mr. R. S. Pearson, C.I.E., F.L.S., Director of Forest Products Research, for permission to publish these results; and to my colleagues of this laboratory for many helpful suggestions.

REFERENCES

(1) Clarke, S. H.: 'The Anatomical Structure of Home-Grown Timbers, and the Relation of Structure to Strength. Elm.' *Forest Products Research Bulletin*, no. 7, 1930.

(2) Forsaith, C. C.: 'The Technology of New York State Timbers.' *N.Y. State Coll. For., Tech. Pub.* no. 18, 1926.

(3) Koehler, A., and Thelen, B.: *The Kiln Drying of Lumber.* McGraw Hill Pub. Co., London, 1926.

(4) Roth, F.: 'Timber: an elementary discussion of the characteristics and properties of wood.' *U.S. Dept. Agric. Divn. of For., Bull.* no. 10, Washington, 1895.

(5) Sponsler, O. L.: 'The Molecular Structure of the Cell Wall of Fibres.' *Amer. Journ. Bot.*, 1928, vol. xv, pp. 525–36.

(6) Stillwell, S. T. C.: 'The Seasoning of Timber.' *Forestry*, 1930, vol. iv (1), pp. 34–9.

(7) Wagner, J. B.: *Seasoning of Wood.* D. van Nostrand Co., New York, 1917 (p. 131).

(8) Yule, G. U.: *An Introduction to the Theory of Statistics.* Griffin, London, 1919.

EXPLANATION OF FIGURES

Figures 1 *a*, 2 *a*, 3 *a* and 4 *a*, are printed on transparent paper, so that drawings of individual elements may be compared by superimposition.

FIG. 1 *a*. *Grevillea robusta*. *Camera lucida* drawing (× 200) of outline of lumina of three vessels in a dry, transverse section.

FIG. 1 *b*. The same, in a saturated condition.

FIG. 2 *a*. *Grevillea robusta*. *Camera lucida* drawing (× 470) of elements in a dry, transverse section. *m.r.* = medullary ray cells; *f.* = fibre; *w.p.* = wood parenchyma; *v.* = vessel.

Fig. 2 *b*. The same, in a saturated condition.

Fig. 3 *a*. *Ulmus montana*. *Camera lucida* drawing (× 33) of a transverse section in a dry condition. Fibre groups shaded. *m.r.* = medullary ray; *v.* = vessels.

Fig. 3 *b*. The same, in a saturated condition.

Fig. 4 *a*. *Rapanea rhododendroides*. *Camera lucida* drawing (× 470) of a dry tangential section showing part of a medullary ray.

Fig. 4 *b*. The same, in a saturated condition.

PLATE IV

SOME FOREST PESTS IN BILBERRY AREAS[1]

BY C. C. BROOKS
Imperial Forestry Institute, Oxford

INTRODUCTION.

THE Forestry Commission have recently established plantations in the hilly districts of the Welsh border counties, and these have suffered locally from some remarkable caterpillar attacks. The areas concerned were formerly used for grazing sheep, often overrun with rabbits, and the sudden change of cultivation has, as is so often the case, produced a number of insect pests.

The hill-sides can be classified roughly into three zones:

(1) a lower zone of grassland with or without bracken;

(2) a middle zone in which the vegetation is mainly bilberry;

(3) an upper zone of heath land.

It is in compartments in the middle bilberry (*Vaccinium myrtilus*) zone, roughly between the 1,400 and 1,700 feet contours, that most damage has been done. The reason for these outbreaks is not difficult to understand. In neighbouring areas still utilized for grazing sheep the bilberry is found to be close-cropped and plentifully mixed with short grasses which are better able to withstand browsing, and under such conditions the population of numerous species of caterpillars and sawfly larvae of which the bilberry is the normal host-plant is reduced to a minimum. This is due not only to a shortage of the caterpillar's food, but also to the fact that many of the larvae are inevitably, if accidentally, devoured and destroyed by the sheep as they graze.

In such areas the pests flourish in numbers only on the ungrazed bilberry on the ledges of the ravines and other inaccessible places. When an area is enclosed prior to planting, the sheep are removed and the rabbits exterminated so that the ecological equilibrium is abruptly disturbed. The bilberry, no longer grazed, flourishes and dominates the grasses with which it previously existed on equal terms, and large patches of pure bilberry vegetation are thus formed. The caterpillars now have an abundant food-supply and, freed from their previous checks, increase rapidly in numbers, so much so, in fact, that over large areas the bilberry, despite its new luxuriance, is completely defoliated by them. It is in such areas that the caterpillars assume economic importance, as, unfortunately, they do not restrict their diet to the normal host-plant, but also attack young plants of Norway spruce, Sitka spruce, European and Japanese larch, Scots pine, and Douglas fir, as well as natural seedlings of Rowan. In fact it is improbable that any species of young tree suitable to the area is immune from their depredations.

[1] *Editor's note.* It is with great regret that we have to record the death of Mr. Brooks on the 28th June, 1930, as the result of a motor accident. This paper had been written for *Forestry* and was relatively in final form. Dr. R. N. Chrystal kindly prepared it for publication.

The first indication, and it is believed the first record of these caterpillars as forest pests in Great Britain, was reported by the District Officer, F. E. B. de Uphaugh, who first noticed their attacks on some P. 27 compartments in the Newcastle plantations, Cascob, Radnorshire, in the summer of 1927. Since then the attacks have been noticed on other areas, and one of the caterpillars was reported by the District Officer of the Tintern area, Mr. G. B. Ryle, as a pest on several of his plantations.

A brief investigation has, therefore, been undertaken, most of the details of which have been gathered during a few short personal visits to the Cascob area, and with the assistance of the District Officer and Mr. Harrison, the local resident forester.

In addition to two unimportant sawfly larvae there are five different species of Lepidopterous caterpillars present in these epidemics. Of these, however, only two—*Tortrix viburniana* Fabr. and *Eupethecia nanata* Hübn.—occur in sufficient numbers to render them of economic importance, and, as little is known about these pests, some details of their biology are given.

TORTRIX VIBURNIANA FABR.

The only previous reference to the depredations of this species which the writer has discovered is to be found on p. 262 of the *Zeitschrift für Pflanzenkrankheiten*, Bd. 4, 1889, where Skøyen, in an entomological report on the Swedish forests, briefly records the caterpillars as attacking young plantations of larch, Scots pine, and Silver fir. He notes that the caterpillar's natural food appears to be bilberry and that the attack lasted for three years, 1886 to 1888.

The moths have a wing-span ranging from three-quarters of an inch to one inch. They vary in colour from a dark straw, through shades of brown and reddish-brown to almost black. The fore-wings are narrowed anteriorly, and especially in the females there is occasionally a faint transverse ferrugineous mark about the middle of their length. The hind-wings are dark grey.

In 1929 the first moths, mostly males, were seen on 11th June, but as a week after that date many caterpillars appeared to be still only in the fourth instar, it is probable that the time during which the adults are to be found extends over a long period, possibly until the middle of August. They are on the wing chiefly at sunset, but show an incipient activity about midday. For the remainder of the time they remain at rest on the bilberry or other foliage unless disturbed, when they dart away with short, dazed flights. Neither oviposition nor the eggs have been observed, but it is presumed that the latter resemble the typical flat disk-shaped Tortricine type with a thin chorion, and that they are laid somewhere on the host-plant. Measurements taken of the width of the head capsules of the caterpillars fall into six groups, thus indicating that there are six larval instars in the life-history. The younger caterpillars are slightly flattened dorso-ventrally, and are of a yellowish, olive, or slaty-green colour, with the verraculae or little chitinous plates from which the setae arise, standing out as minute light dots. The head capsule,

prothoracic shield, and suranal plate are light brown with small black patches in localized areas.

In the summer and autumn the caterpillars feed on the inner surfaces of the leaves which they spin together with silken threads. On bilberry they draw the leaves towards the stem, and as the shoot elongates they migrate upwards binding leaf after leaf with the web until a tube, sometimes an inch and a half in length, has been formed. On the young conifer transplants the caterpillars draw several needles together, even managing to bend the stiff needles of the Sitka spruce, and they produce small minaret-shaped shelters in which they live. From the number of empty shelters and the few cast skins found within them it is thought probable that the caterpillars often migrate to other branches and plants, abandoning their old homes and binding together new ones. This is rendered even more likely by the fact that throughout their life the caterpillars are extremely active and wriggle backwards violently when disturbed. As a general rule on receiving any unusual stimulus they emerge from the base of their leafy tube and continuing their rapid motion soon reach a place of safety among the dense growth of bilberry roots and mosses below.

Hibernation takes place in the second, third, or fourth larval stage, normally, either *in situ* between the deciduous leaves of the bilberry which fall with the caterpillar to the undergrowth below, or else the caterpillar works its way down into the undergrowth and spins its hibernation chamber there. On evergreens, however, such as crowberry (*Empetrum nigrum*) and young conifers, the caterpillars have been found hibernating between the leaves where they last fed. It is interesting to note that of these found in such exposed situations not one was observed to have died as the result of frost, though the winter of 1928–9 was exceptionally cold. Even on the southern slopes where rapid changes in temperature must have been endured, no mortality was noticed due to this cause. This extreme plasticity as regards temperature appears to be the factor which allows this caterpillar to flourish in equal numbers on the cold northern and the warmer but more changeable southern slopes of the hills.

Towards the middle of April the caterpillars emerge from their hibernation and commence feeding again. (It must be remembered that these dates and others mentioned in this paper are based on observations in 1928 and 1929, which were in many respects exceptional seasons. They are, therefore, liable to vary in future years.) They are now dark-green in colour and turn almost black before pupation, though the lighter-coloured internal organs can still be seen through the thinner portions of the integument, and the light-coloured verraculae still give them a speckled appearance. Feeding takes place as in the autumn but on a much larger scale. Young shoots of pine, &c., can be bound together as they grow and the larva instead of merely eating the surface of the leaf now devours it whole, and may possibly gnaw into the soft, green tissue of the succulent shoot.

A peculiar feature of the spring attack is the occasional deformation of the growing shoot, particularly in larch and Douglas fir, caused by the binding

together of the needles of one side, and possibly aided by injury to the side of the shoot itself. The uninjured and unfettered side continues to grow but the attacked portion is unable to do so to the same extent, with the result that the shoot becomes bent into a sharp curve and may even form a complete loop.

Pupation takes place from the beginning of June in the shelter last inhabited by the caterpillar, and the black pupa wriggles out just before the emergence of the moth. The pupal period lasts from thirteen to seventeen days.

EUPETHECIA NANATA HÜBN.

Other species of the large genus *Eupethecia* have been recorded as occasional orchard pests, but so far as the author can determine entomologists have had no previous occasion to rank the present species, *Eupethecia nanata*, as economically undesirable. It is with regret, therefore, that he must add its name to the long black list.

The moths have a wing-span of four-fifths of an inch to one inch. The abdomen has a brownish sub-basal band and blackish, lateral spots. The fore-wings are elongate, grey, with fine dark, grey-brown angulated lines; the transverse bands are separated by fine, white lines, while the veins are partly black marked; there is a subterminal white line which broadens to a spot in the angle formed by the posterior and lower margins of the wing; a black discal mark preceded by a white spot; and an oblique whitish, apical dash. The hind-wings are pale-grey, mixed with white, with fine grey lines which are only dorsally distinct; there is a grey discal spot, and the fine hairs which fringe the wings are conspicuously barred.

The author was unable to visit the plantations in May when the adults were on the wing, so that no details of their activities nor descriptions of the eggs are available. By the second week in June 1929, the caterpillars had attained an advanced stage though the exact number of instars has not been determined. They are pale-green with a darker dorsal line and a series of three dorso-lateral, irregular white lines on either side. The head capsule, prothoracic shield, and suranal plate are dark-brown. They are stouter and less agile than the caterpillars of *Tortrix viburniana* from which they can be distinguished at once by the possession of only one pair of abdominal prolegs besides the anal claspers, instead of four pairs.

The duration of the caterpillar stage in this species is remarkably short. The first eggs hatch probably towards the end of May, while the last caterpillar recorded pupated on 18th July. In correlation with this brief period of activity the caterpillars eat ravenously, but they are more specific to the bilberry than the *Tortrix* and do not attack the young trees to any great extent until the supply of bilberry is exhausted. When young they feed, like *viburniana*, between leaves which they bind together in a similar manner, but as they increase in size they emerge and feed uncovered on the shoots. The rapidity with which they can defoliate a bilberry area is remarkable. Looking at a hill-side, brown patches will appear in a day and grow rapidly until, in

less than a week, what was once verdant green will be nothing but a wilderness of barren bilberry stalks with scarcely a leaf to be seen. Such a phenomenon was observed at Cwm Mawr in the spring of 1928 when extensive defoliation of the young forest trees also occurred. Pupation takes place in early August after the caterpillar has burrowed down among the roots in the peaty soil. In this stage it remains quiescent for eight of nine months until the moth emerges the following spring.

THE SECONDARY EQUILIBRIUM.

The ecological aspect of our introduction terminated in a pessimistic strain but it must be stated now, that direct observation has shown that the epidemics of these caterpillars persist for a maximum of three years only, while in many areas the population is reduced to negligible proportions after only one year's abundance.

Near Cascob in the most dense bilberry patches still grazed by sheep, the average population of the *Tortrix* caterpillars in September is less than one per ten square yards. Two seasons after enclosure the population had risen to between sixty and seventy per square yard. Three seasons after enclosure five per square yard was just above the average, and there is every likelihood of a further decrease in the future as the bilberry becomes overgrown by the young trees.

Counts of the population of *Eupethecia* caterpillars in early June showed a very similar rise and fall in their numbers during the same seasons. This secondary equilibrium has been brought about naturally by a new set of ecological factors, which, however, it has been found impossible to work out in detail. Both caterpillars in their habitat on the grazed bilberry are parasitized to the extent of only 7–10 per cent. At the height of their abundance in 1928 the *Tortrices* suffered a 25–30 per cent. parasitism, three different types of hymenopterous larvae being responsible, but the fact that in the following year, when the caterpillars were much more scarce, the percentage dropped to 17 shows that these parasites are not primarily responsible for the great diminution in numbers of the pest. In June 1929 50–60 per cent. of the *Eupethecia* caterpillars contained the larvae of a tachinid fly.

Birds, however, play a most important part in reducing the numbers of these pests, and they particularly attack *Eupethecia nanata*. Large flocks of starlings and sea-gulls have been noticed by the forester to appear in the morning, and after feeding upon the areas all day, to fly back to the valleys again in the evening. These flights continued for several days about the middle and end of June, and as this is the time during which the *nanata* caterpillars feed unprotected on the shoots, and is just previous to the time of the most serious attack on the young conifers, the importance of these birds cannot be overestimated. When the author visited the plantations in early June 1929, an average of about thirty caterpillars was found per square yard, but later, after the birds had ceased to visit the area, an hour's search produced no more than six specimens.

Probably the most important of these secondary controlling factors is the change which takes place in the character of the humus immediately underneath the vegetation. In the original condition, where grazing still occurs, this zone is shallow, well aerated, and in fine weather often becomes comparatively dry, but in enclosed areas under the more luxuriant bilberry growth it rapidly becomes deeper, denser, more acid, and continuously moist. As each of the pests spends a considerable proportion of its life-history in this zone—*viburniana* hibernating in the caterpillar stage, and *nanata* the whole of its long pupal stage—it is possible that the encouragement which the latter conditions would give to bacterial and virus epidemics, especially when the pests are in large numbers, accounts for the natural check observed upon their outbreaks. Several specimens of *nanata* pupae were found *in situ*, which had evidently succumbed to this type of disease, and there was a noticeable decrease in the post-hibernation population of the *viburniana*, which, in over four marked square yards was only 8 per cent. of the population of the previous autumn. Owing to the short time at the author's disposal, and the difficulty of obtaining the necessary extensive data, it is, however, impossible to make any definite statement upon this point. The numbers collected, while consistent with the hypothesis, are not sufficient to prove it.

No data at all have been collected upon the mortality due to the activities of the numerous shrews and voles which are present on the area, nor to the depredations of pupal parasites which may possibly alternate between one species and the other. The action also of the various physico-chemical factors is unknown. What is important is that these pests are merely of temporary economic importance during an interval of two to three years (this is also borne out by Skøyens' observations in Sweden) between the interruption of one and the establishment of another ecological equilibrium.

CONTROL MEASURES.

The application of the usual mechanical control measures against these pests is rendered extremely difficult on account of the widely different life-histories of the two species, the inclemency of the climatic factors, and the inaccessibility of the areas attacked. Spraying with a stomach poison such as lead arsenate would be only doubtfully economic even along the sides of the streams in the valley-bottoms. The labour of carrying sufficient water up the steep hill-sides would be too expensive. Even then, there are few days in the year when the damp, northern slopes dry sufficiently to make spraying possible.

Contact insecticide spraying against the eggs would be impossible as it would have to be carried out at least three times a season.

The high winds usually experienced in these hills, and the dampness of most of the northern slopes, would also prevent successful dusting operations on most days of the year, whether the dust was a stomach poison or a fumigant, while hand-picking is, of course, absolutely impossible as a control. The burning of the natural vegetation prior to planting has probably very little

effect upon these insects. The caterpillars of *Tortrix viburniana* are extremely active, and it is unlikely that a light fire will affect the depths of the soil to which they can penetrate. The *Eupethecia nanata* in the autumn, when burning is usually practised, is also in the damp undergrowth in the pupal stage, and any slight mortality which the fire inflicts upon the population will probably be counterbalanced by the lack of food for the larvae when they appear, and consequently a heavier attack on the young trees. The caterpillars appear to be adapted to the habitat of a dense, low vegetation, and it was noticeable that young rowan trees a few feet above the level of the surrounding bilberry were not attacked. In order to anticipate this condition with the young conifers, turf-planting with larger transplants was tried by the District Officer. Owing, however, to the exceptional season of 1928–9, to the lightness of the soil, and to a certain amount of wind throw, these experiments were a failure, but with deeper turves and a more normal year, this method may prove to be more successful.

Bird-nesting boxes were also erected at intervals on the trees in the valleys. The altitude was, however, probably too high, or the situation too exposed, as there was no sign that they had been utilized even as refuges. The main bird population of the areas continued to be diurnal. The introduction of parasites to the areas would also appear to be unprofitable. Enormous numbers would have to be introduced to make any appreciable difference to the caterpillar population before it again finds its equilibrium, and this would entail too great a cost.

It is doubtful, moreover, whether these pests are sufficiently important to warrant such drastic and expensive treatment. In 1927 and 1928 they did considerable damage in several compartments at Cascob, and it was estimated that 75 per cent. of the plants had been attacked, of which 25 per cent. were supposed to be beyond hope of recovery. This figure has since been shown to be much too high, and it is doubtful whether the loss will exceed 10 per cent. even in the worst compartments. This, however, is not evenly distributed, and in small patches, rarely more than ten yards square, there may be total loss. The coincidence that attack takes place during the period of post-planting check, and that the transplants at Cascob were definitely of a low grade tended to the over-estimation of the amount of damage done. The fact that the caterpillars keep the bilberry in natural check is definitely advantageous. They lessen the chances of the young trees being overgrown by this weed, and thus save more extensive weeding operations, while they also prevent the formation of large quantities of sour bilberry humus, which is detrimental and even fatal to the trees' growth.

It is improbable that more economic measures can be taken than to ensure the planting of better quality transplants in the bilberry areas. These will suffer a post-planting check for a shorter period, and will thus be able to recover more rapidly from any injury they may receive. Soil and other conditions permitting, preference should also be given to larches, which being deciduous are better able to withstand defoliation than other conifers, and if losses ensue

it will almost certainly be cheaper to beat up the areas where necessary after the cessation of the attack, than to try and prevent them during its progress. If these measures are carried out the author believes that the forester will be able to ignore the presence of these caterpillars, and will reap as much benefit from them by their natural control of the bilberry as he will lose by any damage they may do to the young trees.

In conclusion the author wishes to acknowledge his indebtedness to the Forestry Commissioners under whose grant to the Imperial Forestry Institute the work was carried out, to Mr. Britten, of the Manchester Museum, who kindly identified the moths, and to J. Shaw, artist to the Imperial Forestry Institute, who was responsible for the drawings of the two caterpillars. Finally, he desires to express his thanks to the District Officer, Mr. F. E. B. de Uphaugh, and the Forester, Mr. Harrison, for the great assistance they have rendered him in this work.

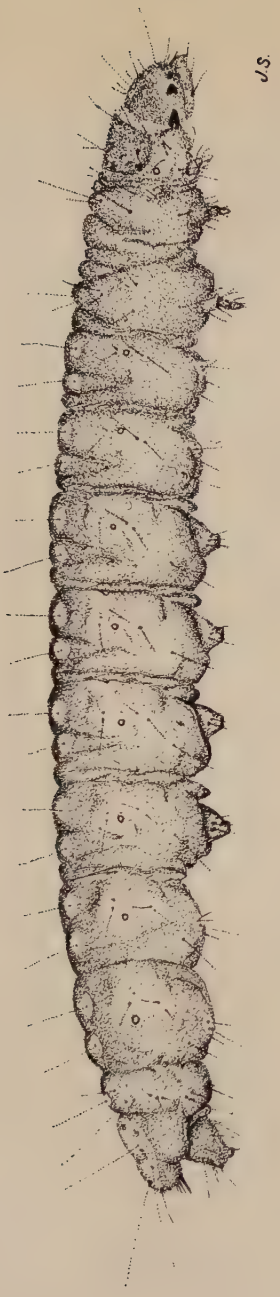


FIG. 1. Caterpillar of *Tortrix viburniana* Fabr. × 15

FIG. 2. Caterpillar of *Eupithecia namata* Hübn. × 10

PLATE VI

SOME EXPERIMENTAL STUDIES ON THE ARTIFICIAL REGENERATION OF OAK

BY W. H. GUILLEBAUD
Chief Research Officer, Forestry Commission

INTRODUCTION.

THE *raison d'être* of the so-called artificial methods of establishment is obvious enough—it is impossible to regenerate naturally without mother trees—but we are often faced with the necessity of establishing oak on ground which is bare of trees; either the previous tree-crop has been cut, or the land may be virgin, that is under grass or some other form of utilization. Even where an old crop of oak is present there are many conditions under which natural regeneration is impracticable, and resort must be had either to direct sowing or to planting.

During the last ten years the Forestry Commission has established a very considerable area of land with oak—partly by direct sowing, but for the most part by planting. The results have been somewhat disappointing. In the course of this work two difficulties have been experienced, in the first place the slow growth of the oak, and, secondly, the tremendous growth of weeds, notably coarse grasses, brambles, and briars. The second difficulty, of course, is greatly aggravated by the first. If the oak got away quickly it would soon be out of reach of the weeds, and the fact that intensive weeding might be necessary for the first year or two would not greatly signify. The trouble is that often the oak grows so slowly that from six to ten or more years may elapse before the majority of the plants have got their heads above the weeds. The oak plants are often very difficult to find under the mass of intertwined bramble and grass, and it is easy to see that under such conditions weeding is a slow and expensive process. It is natural then that we should want to overhaul our existing methods, and see if some way cannot be devised to get over these difficulties. The problem has been tackled by experiment, that is to say, we are putting a whole series of questions to Nature in the anticipation that the answers will throw light on some, at least, of the underlying factors. Putting questions to Nature is one thing, and getting dependable answers is often quite another. So much depends on the way in which the questions are put, in other words, on the planning and lay-out of the experiments. Briefly, the methods employed have been those of the modern field plot technique with all treatments replicated in small plots on uniform and compact blocks of land. The Latin Square and Randomized Block (2) forms of lay-out have been used in the majority of the experiments with from four to six replications of each treatment and a unit area of one-tenth to one-twentieth of an acre for the individual plots.

The work started in 1927, and as this paper had to be prepared in the early

summer of 1930 the results of three growing seasons at the most were available. Such a period is too short to admit of anything more than a report of progress.

FROST DAMAGE.

One considerable series of questions concerns the factors responsible for the slow initial development of oak when artificially sown or planted. It is conceivable, no doubt, that the real trouble lies in the inherent nature of the oak plant itself, that no matter what precautions are taken, development will still be relatively slow; this cannot, however, be assumed without proof, and we know definitely of some and can guess at other factors which do operate to check growth. One of the most obvious of these is undoubtedly frost. Unfortunately frost is a difficult factor to study by means of field plots owing to its uncertain incidence. Both this and last season have been exceptionally free from late frost, and a sheltering experiment in Dymock Forest in Gloucestershire has been without result. The one point that stands out is that even in the absence of unseasonable frosts the plants have made disappointingly little headway.

OAK MILDEW.

Besides frost, oak mildew must be regarded as a probable factor tending to retard the growth of oak. The extent to which young oak plants are attacked by the mildew appears to vary with the season and with local conditions; for example, the attack is usually more severe where there are oak-stool shoots among the plants than where the oak is planted on bare ground or follows a high forest crop of oak. In a heavy infestation the leaves may shrivel up and growth is obviously checked. An experiment was started last year at Dymock of spraying alternate groups of closely planted one-year oak seedlings (direct sown) with a preparation of colloidal sulphur. Three sprayings were carried out during the growing season, but it was found that, owing to the presence of heavily infested oak coppice, reinfection took place rapidly, and that more frequent spraying would be required to control the mildew adequately. A more intensive experiment in another area gave definite results. Seventy two-year-planted oak were selected in a plantation, only thriving plants with a definite leading shoot being chosen. In order to exclude possible damage from unseasonable frosts each of the plants was surrounded by a number of birch branches stuck into the ground with the tops interlacing over the oak. The branches were kept round the plants during spring and autumn and removed in the summer months and through the winter. Among these seventy plants, twenty were selected at random and sprayed four times during the growing season against mildew. Measurements at the beginning and end of the year (1929) showed that the staked and unsprayed plants had grown on the average 3·5 inches (from 10 inches to 13·5 inches), and the staked and sprayed plants had grown 7·1 inches (from 11 inches to 18·1 inches). The difference in favour of the sprayed plants amounted to 3·6 inches with a

standard error of the difference of ±0·8—a satisfactorily significant difference. Spraying has been continued this season, and the effect appears to be almost equally marked.

ROOT COMPETITION.

A third possible factor is the root competition of the grass and other weed-growth which are usually so luxuriant on typical oak soil. It is known that many plants respond to soil cultivation which both aerates the soil and removes competing weed-growth, so that this appeared to be a question deserving investigation. Seven experiments in six different soil and vegetation types have been carried out. Four of these experiments date from 1927, and in the three growing seasons which have elapsed, sufficient evidence has accumulated to justify the statement that as far as those particular soils were concerned, keeping the plants free from weeds by hoeing, leads to no appreciable improvement in growth during the first three years.

FOOD REQUIREMENTS.

A fourth factor is the question of mineral food requirements, and the possibility of stimulating growth by adding readily available supplies of the more important elements—nitrogen, phosphorous, potash, lime. On this we have ten experiments; of these the earlier ones dealt only with the addition of lime, which was applied both to strips which were dug up in preparation for direct sowing and to seedlings planted out in the forest. In the case of the direct sowing, the seed was sown in prepared patches to each of which two handfuls of powdered lime had been given. When this experiment was assessed at the end of two years it was found that the mean height of the tallest seedlings in each of the patches was in the limed plants 9·4 inches and in the unlimed control 9·5 inches. Thus the addition of lime has so far had no beneficial effect upon the growth of the plants. A similar experiment with one-year oak seedlings gave negative results.

In 1929 and 1930 further manurial treatments were tried, for example, plots have been established, both by direct sowing and by planting, in which seed of perennial lupin has been sown between the rows of oak. In spite of a good deal of trouble from birds the 1929 sowing produced a very fair crop of lupin. This method has been used successfully in Germany and it will be interesting to see how it will work out in this country. In addition to enriching the soil in nitrogen the lupins may be of considerable value in protecting the oak plants from late and early frosts. The effects of basic slag upon oak sowings and of a complete manure consisting of ammonium phosphate and potassium sulphate are also under investigation. There is nothing yet to report on these experiments.

PLANTING DISTANCE AND METHOD.

A fifth question is that of planting distance. Can growth be accelerated by crowding the plants together? There are indications both from the greater success of natural regeneration, where the plants are usually densely crowded,

and from certain close-planted oak woods in the Forest of Dean, which are making rapid growth, that close spacing may help to force the plants upwards and to check that ugly bushy habit that is so commonly found in widely spaced oak transplants, for example, plants put in at 4½ feet by 4½ feet. Nine experiments have been laid down in five different areas to test this point. The spacings tried have varied, but in most cases the comparison is between plants spaced at 4 feet by 1 foot, 3 feet by 2 feet, 4 feet by 3 feet, 4 feet by 3 feet, and 4 feet by 4 feet. Very close spacing of oak seedlings in small groups, putting in the plants at less than 12 inches apart, is also being tried.

Again, there are the vexed questions as to whether a better crop is produced by direct sowing or by planting, and in the case of planting whether it is better to use seedlings or transplants. All these points are being investigated with field plots. The results to date may be briefly summarized as follows. There is not a great deal to choose so far between the growth of direct sown plants and planted one-year seedlings, but if anything the direct sowings appear to have the advantage. In almost every case the one-year seedlings are doing better than the older transplants.

RACE AND TYPE OF OAK.

There is also the question as to the influence of race and type of oak upon rate of growth. In the last few years batches of plants have been raised from ninety different lots of acorns of both sessile and pedunculate oak collected in various parts of England and Wales. These have been planted out in Dymock Forest for future assessment. One particular plot may be mentioned. Sufficient seed was collected from a single large pedunculate oak in Bagley Wood, near Oxford, to plant half an acre of ground in the Forest of Dean at a spacing of 4 feet by 1 foot (one-year seedlings were used). A detailed study of the plants should provide useful data as to the variation occurring in the offspring of a single tree.

In addition to the specific problem of rate of growth in early youth, other matters under investigation include the nursery practice of raising oak, the technique of direct sowing, the degree of weeding necessary in different herbage types, and methods of mixing oak with larch and beech.

NURSERY PROBLEMS.

In the study of the nursery practice of oak we have set out to raise a good type of one-year seedling, and to this end have tried the application of lime, leaf-mould, and lime plus leaf-mould to the seed-beds. The first experiment carried out in 1928 gave the following percentages of Grade I seedlings—which was plants of 8 inches and over. Control (no lime or leaf-mould) 28 per cent. Lime only 34 per cent. Leaf-mould only 38 per cent. Lime and leaf-mould 42 per cent. The lay-out of the plots was in the form of a Latin Square and the significant difference—that is the difference required to give a probability of 20 to 1—was 4·3 per cent. The leaf-mould thus significantly increased the output of larger plants. The following year we again tried the use of

leaf-mould, but this time on English acorns collected in the Forest of Dean and on acorns purchased from Holland. The soil was already fairly well supplied with humus and the application had very little effect on the quality of the plants from the English acorns, but it did significantly increase the percentage of Grade I plants raised from the Dutch acorns.

Another important point in the raising of plants for planting is the question of grading. That is to say, the extent to which it is necessary to discard the small plants. To test this the seedlings raised in 1928 in the plots to which lime and leaf-mould had been added, were lifted and put into four grades by length of shoot, viz. Grade I, 10 inches and over, Grade II, 8 to 10 inches, Grade III, 6 to 8 inches, and Grade IV, under 6 inches. Plants of each grade were planted out in 1928–9 in a Latin Square chess-board, and at the end of the growing season the losses were counted with the following results: Grade I losses 20 per cent., Grade II 27 per cent., Grade III 51 per cent., and Grade IV 67 per cent. The significant difference was low—only 3 per cent. Thus in this particular experiment, on the basis of losses alone, it would probably have paid to discard all the plants under 8 inches, which in this case formed 58 per cent. of the plants in the seed-bed. There is more in it of course than the mere question of initial failures, it may well be that the lower grades may produce trees of inferior form to those of the higher grades.

The control of oak mildew in the nursery has been intensively studied by Steven and others (3) at Oxford; this work showed that the disease can be cheaply and effectively controlled by spraying with finely divided sulphur. Freedom from mildew produces distinctly sturdier and better plants.

DIRECT SOWING.

The technique of direct sowing involves among other things the questions of when to sow the seed, how deep to sow it, and what density to use. A season of sowing experiments was started in the Forest of Dean in 1928, sowing seed in replicated blocks each month from November 1928 to April 1929, and combined with depth of sowing, alternate rows being sown at 2 and 5 inches depth. The seed was sown in drills 4 feet apart at the rate of 15 acorns per yard run. The counts showed that the March and April sowings gave the best germination with nine seedlings per yard run as compared with 4·5 to 6·5 for the earlier sowings. These data refer to the 2-inch depth of sowing. The winter of 1928–9 was unusually frosty, and in the earlier sowings it was difficult to firm the covering soil after sowing; but experience has shown that unless the soil is properly firmed the seed is more liable to attack by birds. The poorer germination in the earlier sowings is probably due, in part at least, to this cause. The trend of results was the same in the 5-inch sowings, but the germination was much lower—only 1·5 to 2 seedlings per yard in the earlier sowings as compared with 3·5 to 4 for the March and April sowings. Thus the deeper sowing rather more than halved the number of seedlings produced. The deeper sowing had also a marked effect on the size of the seedlings at the end of the first growing season, those in the 2-inch sowing averaging 4·8 inches

as compared with 3·4 inches for the 5-inch sowing. It should, perhaps, be mentioned that deep sowing is the standard practice in one forest where a large stock of pheasants is reared by landed proprietors in the neighbourhood. Experience in that area showed that if the acorns were sown in the normal way—about 2 to 3 inches below the soil-level—excessive losses resulted from the birds, but that most of the damage could be prevented by putting the acorns at a greater depth. One object of the experiment just described was to determine how far such deep sowing may be prejudicial to germination and subsequent growth. The whole experiment was repeated in 1929–30 in the Forest of Dean, but has not yet been assessed. It is proposed to repeat the experiment annually over at least five years and to keep temperature and rainfall records in the immediate vicinity of the area. It is hoped that the data provided may throw some light on the climatic and other factors which affect the germination of oak sown direct in the forest.

Next there is the question of density of sowing. This is bound to vary with the quality of seed, climatic conditions, intensity of attack by birds and mice, and so on, but what is required is the minimum density which, under moderately adverse conditions, will give a satisfactorily stocked crop. This experiment has been carried out two years running—in 1929 and 1930—in the Forest of Dean, using the following densities, 10, 15, 20, and 30 acorns per yard run. These correspond for rows 4 feet apart to approximately 200, 200, 400, and 600 pounds of acorns per acre. The 1929 experiment has not yet been fully assessed, but it appears that for the year in question, which was particularly favourable for direct sowing, a density of 10 acorns to the yard was sufficient to provide a satisfactory crop.

WEEDING.

At present, weeding is one of the principal elements in the cost of raising an oak plantation. A large part of the expense is due to the difficulty of finding the small oak plants in the tangled mass of coarse grass, bramble, briar, and blackthorn which usually invades the soil of an oak wood as soon as the trees are cut and the ground exposed to the full light of day. With all the care in the world it is often impossible to avoid mistakes and many oak plants fall victim to the operation which is supposed to save them. A second evil of weeding is that it exposes the oak to frost. As long as the plants are buried in the weed-growth they are almost certainly protected from frost, but when the covering is removed their protection is gone, and an untimely frost may and often does cut them back. On the other hand, to leave the plants untended would often mean that for a considerable number of years the small oak could only be found by cutting in here and there from the sides of the rides. To a forester accustomed to seeing his conifer plants perking up their heads all down the rows at the end of three years at most, such an idea is by no means attractive, and in any case it is a question if the oak plants can survive the smothering. A middle course of action is, of course, possible; to lighten the cover by cutting over the upper weed-growth but without attempting to

find and free the individual oak plants. The problem can only be decided by comparative trial plots coupled with a careful record of the growth from year to year of individual plants. This is being done at Dymock Forest.

METHODS OF MIXING OAK WITH LARCH AND BEECH.

On the present lines on which we are working (close planting), the establishment of a crop of pure oak is an expensive process, especially in view of the fact that early thinnings are usually unsaleable. Moreover, the later introduction of beech, which is generally considered to be desirable if not essential, is likely to present some difficulties. Two alternatives present themselves. On the one hand beech can be planted at the same time as the oak. This would not assist the financial side of the problem, and has the further objection that it is difficult to raise a satisfactory crop in this way. Either the beech outgrows the oak, as is the case in districts such as the Forest of Dean, or the beech may be cut back by frost or sun-scorch and fail to develop satisfactorily. The other alternative is to plant larch with the oak. Larch, though a quick grower, does not cast a heavy shade, and it has the great merit of being saleable from an early age. With a suitable method of mixture the larch can be cut out in the small pole stage and replaced by beech. Thus the larch will provide quick returns and at the same time facilitate the introduction of beech into the oak crop. Some of the best of the middle-aged oak stands in the Forest of Dean were formed from a mixture of larch and oak, and in recent years a good deal of oak has been planted with alternate lines of the two species, the spacing both in and between the lines being 4½ feet. The results in the young plantations have not been altogether encouraging. The slow development of the oak (transplants were used in these plantations) has left it completely behind the larch, and the future handling of the crop presents considerable difficulties. Experiments have, therefore, been started to study other methods of mixing the two species, the object being to separate them as far as possible so that the oak may be brought up in close formation, and thus protected to some extent from the suppressing tendency of the faster-growing larch.

In one such experiment laid down in 1929–30 in the Forest of Dean four methods were employed: a control A, consisting of oak seedlings planted in lines 4 feet apart with 18 inches between the plants in the lines; B, oak and larch in alternate strips, the oak strips consisting of six rows of oak planted at 4 by 1½ feet and the larch of three rows planted at 5 by 6 feet; C, oak and larch in strips, but only four rows of oak alternating with two rows of larch; the fourth plot, D, contained large widely spaced groups of larch set in a matrix of pure oak. There were thirty-six larch in each group planted at 4 by 6 feet, and the groups were about 55 feet apart from centre to centre, equivalent to fourteen groups per acre. It is laid down in the plan that beech shall ultimately be introduced into each of the four plots; in the pure plot A by whatever method shall appear to be most satisfactory when the trees are twenty to thirty years old, and in the remaining plots by removing a proportion of the larch as soon as they have attained a profitable size, underplanting or

sowing with beech, the remainder of the larch being gradually removed as the beech become established. As a subsidiary experiment, alternate strips of oak in plots B and C (that is the plots with alternate oak and larch strips) were planted with plants of local origin and alternate strips with plants grown from acorns obtained from Holland.

Another method of growing oak in mixture with larch is that of planting or sowing the oak in small groups scattered uniformly through a matrix of larch. This method has been tried experimentally in the Forest of Dean and in five other forests in various parts of the country. The first plots of the sort were laid down in 1928–9. Groups 6 feet square were marked out, 16 feet apart from centre to centre, equivalent to 170 groups per acre. Two 1-acre plots were laid out in this way. In one of the plots the groups were dug over a spit deep in preparation for sowing in the spring, when 2½ lb. of acorns were sown in drills in each group. In the other plot thirty-six one-year oak seedlings were planted, the plants being spaced 10 inches apart. Round each oak group 4 grey alder were planted. The ground between the oak groups was filled up with larch planted 5 feet apart. This year it is proposed to have the alder removed from alternate rows of the groups in order to have control plots by which to determine in due course what part the alder will play in nursing up the oak. The method is an adaptation of the group method of planting conifers on difficult sites which was devised by Anderson (1).

The object of the method is that eventually a single oak stem shall come to maturity in each group. In the present case, where there are 170 groups per acre, the number is in excess of final requirements and there will be scope for thinning out in the later stages of the crop. The very close spacing of the oak plants in the groups—the rows being only 10 inches apart—is an attempt to get back to something like natural conditions and by crowding to compel an upward growth. It is hoped that the alder both by its shelter and by its enrichment of the soil will promote the growth of the oak. Another object which it is hoped to attain is to cheapen the cost of tending. With such close planting in the groups beating up should seldom be necessary, while weeding should be very greatly reduced. Lastly, the larch, of which 460 per acre were planted, are to serve partly to provide revenue with which to repay the fairly high initial costs of the method, and partly as a means of introducing beech at an early age into the crop. The beech are to be planted as soon as the first saleable larch poles are cut.

FUTURE LINES OF WORK.

Some of the lines on which it is proposed to extend experimental work in connexion with oak have already been mentioned in this paper. It is also probable that as the existing experimental plots develop, points will appear which will require further working out. At the moment the indications are that the difficulties of establishment are much greater on the heavier clay soils of such districts as the Midlands than on the more permeable loams found in typical oak growing districts in the west of the country.

REFERENCES

(1) Anderson, M. L.: 'A new System of Planting.' *Scot. For. Journ.* 44, no. 2, 1930, pp. 78–87.

(2) Steven: 'Nursery Investigations.' *Forestry Commission Bulletin*, no. 11, 1928, Appendix IV.

(3) Woodward, Waldie, and Steven: 'Oak Mildew and its Control on Forest Nurseries.' *Forestry*, iii (1), 1929, pp. 38–56.

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1930.

THE meeting this year was held at Bristol, when Sir John Stirling-Maxwell, Bart., was chairman of Section K.* (Forestry), and Dr. E. V. Laing, secretary.

The following is a list of authors and titles of papers:

Chairman's Remarks.

Cultivation of Hardwoods. Mr. D. W. Young.

Our British Grown Hardwood Trees and Timbers. Mr. A. Howard.

Some Experimental Studies on the Artificial Establishment of Oak. Mr. W. H. Guillebaud.

Preservation of Red-Wood Forests of the Western States. Professor D. H. Campbell, Stanford University.

The Measurement of Standing Trees. Mr. J. Macdonald.

Some Notes on the Biology of *Xylonomus brachylabris* Kr. (Hymenoptera, Ichneumonidae), a Parasite of the Larch Longhorn Beetle, *Tetropium gabrieli*, Weise (Coleoptera, Cerambycidae). Dr. R. N. Chrystal and Mr. E. R. Skinner.

Some Notes on the Biology of *Xyphidria prolongata* Geoffr. (dromedarius F.), and its Parasite *Thalessa curvipes* Grav. Dr. R. N. Chrystal and Mr. E. R. Skinner.

Joint Discussion with Section M (Agriculture): 'Mineral Nutrients of Plants.' Forestry outlook dealt with by Mr. G. K. Fraser.

The Afforestable Land of Great Britain. Mr. W. L. Taylor.

A Preliminary Report on a Recent Investigation of the Forest Floras of Northern Rhodesia, Nyasaland, Pemba, and Zanzibar. Dr. J. Burtt Davy.

The Relation of Frost Damage to Larch Canker. Mr. W. R. Day.

Observations on *Armillaria mellea* in Pure Culture with Certain Conifers. Dr. M. C. Rayner.

Diagnosis of Decay in Timber. Mr. K. St. G. Cartwright and Mr. W. P. K. Findlay.

The Moisture Content of Wood in Relation to Hygrometric Conditions. Mr. R. A. G. Knight.

The Tertiary Wall of Wood Fibres. Mr. S. H. Clarke.

Antiseptic Treatment of Some Home-Grown Conifers. Mr. J. Bryan.

EUROPEAN BEECHWOODS

A NOTE BY A. S. WATT

THE recent advent of ecology into the ranks of organized bodies of knowledge holds a special interest for foresters. It is true that the content of the subject is much wider than that of silviculture and its aim not primarily economic, but its achievements during a vigorous youth show that the pursuit of knowledge for its own sake may be happily combined with the pursuit of knowledge for use. Fundamentally, the silviculturist is interested in the behaviour of trees in communities; in problems of establishment, maintenance, and rejuvenation; in growth and in the reactions of the environment to the forest. All this is pure ecology, and inasmuch as behaviour is an attribute of life, it is immaterial whether the forest is natural or artificially started and controlled.

Silviculturist and ecologist have in the beech a common interest, and, if the point of view does not always coincide, the work of each is worthy of attention by the other. Silviculture, being first in the field, has amassed a vast literature to which there are constant additions, because the continued usefulness of the beech under changed economic conditions maintains the forester's interest. It is not too much to claim that beech is the pivot round which the development of central European silviculture has taken place; and it says much for the art of the forester when we realize that without its use much that is forest would cease to be productive.

In this vast literature the ecologist finds much of interest and value. But he also makes positive contributions, for he focuses upon the forest the light emanating from the study of plant communities in general. To him the forest is not merely a collection of trees showing a certain degree of density and rate of growth; it is a community of animals and plants living together in a more or less intimate and intricate relationship. The tree dominates; it is the primary object of interest. But the well-being of the tree is affected for good and for ill by its animal and plant associates. To the silviculturist, forest zoology comprises the study of animals hostile to trees, but all animals, hostile, beneficial, and indifferent form the subject-matter of forest zoology in the conception of the ecologist. This example illustrates the point of view, a positive contribution worth exploitation (particularly in the field of forest mycology). Generally, by the development of ecology silvicultural concepts gain in meaning. They are placed in a larger setting and may be viewed against the ecological background of a larger canvas.

Beech is a tree about which we do know something, but the literature is scattered, written in several different languages, and much of it published in obscure and relatively inaccessible journals. Also, among living workers the ways of looking at beechwoods vary. It was, therefore, a happy inspiration of

Professor Tansley's to bring together representatives from different parts of Europe 'to contribute to our common knowledge of forest communities dominated by *Fagus silvatica*'. A day in the Phytogeography and Ecology Section of the Fifth International Botanical Congress (Cambridge, 1930) was set aside for the reading of papers on this subject. The following contributed: the parts of Europe dealt with by each are given in brackets.

Dr. Rübel (Switzerland, Chairman), Dr. F. Markgraf (Germany and Austria), Professor K. Domin (Czecho-Slovakia), Professor W. Szafer (Poland), Professor N. Stoyanoff (Balkan Peninsula), Professor E. V. Wulff (Crimea), Forstmeister A. Uehlinger (Switzerland), Professor C. H. Ostenfeld (Denmark), Mr. B. Lindquist (Sweden), Professor A. G. Tansley and Dr. A. S. Watt (Great Britain).

To ensure uniformity of treatment a synopsis of the subject-matter under numbered headings was circulated to each participant. This is an obvious advantage, allowing immediate contact and enabling any one to compare aspects of the subject with a minimum of trouble. It also brings out the gaps in our knowledge, for the diversity of training, outlook, interest, and need in the different countries of Europe leads to the placing of emphasis on some aspects of beechwoods to the neglect of others. The position in Denmark and in this country affords a good example. The pioneer work of P. E. Müller on beechwood soils set the course along which much of the ecological work in Denmark has moved; in this country biotic factors have been stressed. Yet the lack of regeneration in Denmark is by no means wholly attributable to soil degradation, as the following analysis made in Rude Skov in July 1925 shows. In one square yard there were 43 seedlings, of which only 1 was normal, and even that had *Typhlocyba* and *Phyllaphis* on it. Of the 42, 4 were dead and much decayed, whilst the remaining 38 had, owing to nibbling, only vestiges of cotyledons and leaves, and were in a dying state. Similarly, knowledge of beechwood soils in this country is fragmentary. In this discovery of deficiences in our knowledge lies much of the usefulness of the symposium. But the main object is to consolidate our knowledge of beechwoods with a view to renewed attacks supported by reinforcements both in knowledge and in mutual understanding.

The synopsis is reproduced here; its comprehensiveness needs no comment.

1. Definition of areas dealt with.
2. Altitudinal limits, upper and (?) lower, on different exposures (i.e. to points of the compass). Steepness of slope. Effect of winds.
3. Range of the chief climatic factors within which the beech forests exist.
4. *Soils.* Nature of rocks on which the forests occur. Characters of soil (texture, humus (amount and nature), soil reaction, lime content, &c.). Amount and range of water content.

(*a*) of the layer of soil containing the feeding roots of the beech.

(*b*) of the *surface* layer.

Depth of permanent water-table, if relevant.

5. Character, dimensions, and spacing of mature trees. Age?
6. Regeneration of beech within the forest.
7. Degree of dominance of the beech. Mixture of other trees.
8. Transitions to other types of forest.
9. Observations on 'climatic' factors (light, air, moisture, &c.) beneath the shade of the forest.
10. Shrub vegetation below canopy.
11. Ground vegetation, how far uniform or diversified. Societies of the ground vegetation (vascular plants).
12. Bryophytes, lichens, algae, fungi. Mycorrhiza.
13. Exclusive species of beech forest. Causes of exclusiveness.
13*a*. Would you regard the beech forest as a single natural unit? Or would you regard it as composed of distinct and separate communities?
14. Exploitation of the forest, and any changes resulting therefrom.
15. Effects of grazing in forest (sheep, goats, cattle, &c.). ? Fires.
16. Effect of other animals or parasites.
17. *Succession.*
    (*a*) Development of beech forest from other types of vegetation.
    (*b*) Changes in beech forest tending to supersede it by other types.
18. Available data relating to the past history (records) of the forests described.

The twenty-five minutes allowed to each contributor proved quite inadequate for the reading of his paper in full, and the time was used as each thought best, some in the attempt to cover the whole field, others to emphasize selected aspects. Hence it is impossible to give now a considered digest of the subject as a whole. The summaries which appear in the Abstracts of Communications are useful, but every one interested is glad to know that through the kindness of Dr. Rübel the papers are to be published in full from the Rübel Institute, Zürich, and it is cause for satisfaction to know that efforts are being made to make the treatment of European beechwoods as complete as possible by inviting contributions from other parts of Europe not covered at the Congress.

The symposium ought not to be considered apart from the Beechwood Excursion attended by the readers of papers and by Professor Cowles, of Chicago—a pioneer ecologist in America. There were twelve in all, including representatives from eight European countries. The excursion was organized to demonstrate the chief results so far obtained from the study of beechwoods in the southern part of England, and to show certain aspects not clearly demonstrable in some European countries, where nearly all the beech is under forest management. The excursion lasted a week, during which the South Downs, Burnham Beeches, the Chiltern Hills, the Cotswolds, and Symond's Yat were visited. I do not propose to describe the itinerary in detail, but shall

summarize points of interest arising out of the symposium and the excursion together.

Towards the north-western and western limit of its range the beech is a tree of the plains and lower mountain slopes, but towards the south-east and south it forms a mountain belt rising above the steppe climate on the one hand, and the Mediterranean climate on the other. The lower altitudinal limit would appear to be determined by inadequate rainfall; 550 mm. (21·6 inches) per annum is approximately minimal. This value is approached in East Anglia, where the beech is not native. But the boundaries of natural beech are not stable; in some parts it is extending its range, as it is also invading the coniferous belt above the beechwoods in SE. Europe; in others (Poland) it is apparently retreating, independently of man.

The survey brings out the preference of the beech for calcareous soils, but it is by no means confined to them, and in Bulgaria and East Macedonia it evidently prefers siliceous soils. Brown earths provide the conditions for its maximum development, where the pH shows mean values. At its eastern, north-western, western, and altitudinal (central Europe) limits, beech is also found on very acid soils—the highest acidities, pH 3·7 and pH 3·8, being recorded from Poland and this country respectively. On soils of this high acidity the beech growth is poor, as was demonstrated on the Chilterns. But acidity by itself is not apparently the limiting factor, for good beech growth is found on soils with a pH of 4·2–4·4 (surface 6 inches). The question of soil degradation under beech has been receiving attention in this country for some time, and I hope to publish some account of it shortly.

In central and western Europe the beechwoods are practically pure, but towards the east several species of broad-leaved trees—*Acer* spp., *Fraxinus* spp., *Ulmus montana*, *Tilia* spp., and *Carpinus betulus* and *Abies alba* (*pectinata*)—maintain themselves in larger or smaller numbers in competition with the beech. In this country at Symond's Yat—the westernmost extension of native beech in this country—there is a corresponding wealth of broad-leaved trees, but their behaviour in beech high forest is unknown, as no such woods exist.

Our visitors were much struck by the floristic poverty of the South Downs and Chilterns plateau beechwoods, but on the Cotswolds they saw a much more varied and abundant herbaceous undergrowth—the nearest they had seen in this country to continental beechwoods of the better sort. The abundance of evergreens—*Ilex*, *Taxus* (we visited Kingly Vale—'the finest Yew-wood in Europe'), and the *Rubus fruticosus* undergrowth—Atlantic features—much impressed the continental members of the party.

On the Continent, where the bulk of the woodlands is under forest management, there is not the same opportunity for studying succession as we have in some parts of this country, and we were fortunate to be able to demonstrate this natural process on the Goodwood and adjoining estates, where it is, perhaps, more convincing than in any other part of the country. Members of the party hitherto lukewarm or hostile to the dynamic view, agreed with the interpretation that beechwood forms the climax of a series of communities whose

character varies somewhat with soil conditions, but which follow each other in the generalized succession: grassland, scrub, ash and/or oakwood, beechwood. Several of these series are distinguished, the differences in the corresponding seral and climax communities being evident in the rate of growth of the trees and their floristic cortège. In other words, types comparable with quality classes are recognizable from a study of the subsidiary vegetation.

In the last few years by the study of the pollen found in peat the history of the beech in Europe since the last ice age is now much better known. From the refuges in south-east Europe the beech spread north-westward to central Europe. In Boreal times it existed in the eastern Alps, but did not appear in Germany until Atlantic times, when it spread eastwards to Poland (Atlantic period) and to East Prussia in the Subboreal. From central Europe it spread west and north-west to Denmark and Sweden. With regard to this country no evidence placing the nativity of the beech beyond doubt exists.

It is a pleasure to have this opportunity of placing on record the cordial thanks of the members of the excursion party to Professor Tansley for his generous hospitality and his care for our comfort. By his interest in the development of scientific forestry, and by his initiation of a method of consolidating our knowledge of trees, he lays all foresters under deep obligation to him.

CONFERENCE ON THE SYSTEMATIC ANATOMY OF WOOD

BY B. J. RENDLE

THE Fifth International Botanical Congress, which was held in Cambridge during August, provided opportunity for more or less informal discussions on special branches of botany which for one reason or another could not be adequately treated in the official meetings of the Congress. Earlier in the year a proposal was made public, by means of a circular letter, to hold an informal conference on the Systematic Anatomy of Wood. This subject is one which has been developed considerably in recent years, particularly in the field of forest product research, and it was thought that a good purpose would be served if workers in different parts of the world could meet and discuss matters of common interest. Those who have been engaged in the critical anatomical study of timbers have found that the terms commonly employed in general plant histology are not always adequate to describe the special structural characters of wood, and it has consequently happened that terms already in existence have been used in special senses, and new terms, whose meanings are not always clear, have been introduced. From the numerous anatomical descriptions of timbers which have been published in the last few years, it is apparent that the questions of terminology and method of description have reached a stage where co-operative action is necessary to bring about some measure of standardization. It is scarcely necessary to enlarge on the need for action, but, if justification were required, it should suffice to mention that the advantages likely to accrue from standardization are at least twofold. Standard terminology is essential, firstly for the identification of unknown samples of wood from descriptions, and, secondly, to enable different authors' descriptions to be collated for the preparation of monographs or for general systematic purposes.

The response to the proposal to hold an informal conference showed that there was a very general feeling in favour of co-operation on the lines suggested. In addition to the opinions voiced at the meetings, many letters were received from wood technologists who were unable to attend but who were in sympathy with the objects of the conference. Suggestions were put forward from more than one quarter that the scope of the discussions should be broadened so as to include other branches of wood technology. While there was no lack of support for the principle of extending the movement of co-ordination, limitations of time prevented any departure from the line of discussion originally proposed. In the course of the week three public meetings were held in the Department of Forestry. At the first meeting the principle of international co-operation was approved, and it was decided to investigate the possibility of forming an international association. A committee was appointed to prepare

a draft constitution, and at a subsequent open meeting this was considered in detail. Owing to certain international legal difficulties it was decided to leave the formal organization of the association in the hands of a committee, including representatives of Great Britain, U.S.A., France, Belgium, Holland, Germany, and Australia. The name, object, and activities of the association were as follows:

The Association shall be called the *International Association of Wood Anatomists.*

The object of the Association is to advance the knowledge of wood anatomy in all its phases.

The activities of the Association shall be:

(*a*) To interchange views and information through correspondence and meetings.

(*b*) To facilitate the collection and exchange of materials.

(*c*) To work towards standard terminology and descriptions.

(*d*) To stimulate the publication of scientific works and abstracts.

(*e*) To encourage and assist the study and teaching of wood anatomy.

(*f*) To engage in any other activity consistent with the object of the Association.

Before the close of the Conference an invitation was accepted to hold a meeting in Paris in the summer of 1931, during the *Congrès International des Bois tropicaux et sub-tropicaux.* In the meantime it was desired to make the aims and objects of the Association as widely known as possible and for this purpose Professor S. J. Record consented to place the journal *Tropical Woods* at the disposal of the Association. A full account of the meetings will appear in the December issue of that journal. Any persons who are interested in the activities of the Association are invited to communicate with the Secretary of the Organizing Committee, Professor S. J. Record, Yale School of Forestry, New Haven, Connecticut, U.S.A., or with Mr. E. H. B. Boulton, Department of Forestry, Cambridge, Dr. L. Chalk, Imperial Forestry Institute, Oxford, or Mr. B. J. Rendle, Forest Products Research Laboratory, Princes Risborough, who are the representatives of Great Britain on the Organizing Committee.

This informal Conference has already been of value in establishing contact between workers who knew little of each other previously. There is good reason to hope that it will prove to be the first of a series of meetings of a truly international character covering the broader field of research which has as its centre the systematic study of wood structure. The important question whether these meetings should be held independently or in connexion with some series of larger conferences has yet to be decided. As at present conceived, an International Association of Wood Anatomists could scarcely lay claim to a membership large enough to justify independent conferences; but it is, perhaps, not beyond the bounds of possibility that in the future its meetings may form a section of a regular series of conferences embracing the whole field of Forest Products Research.

THE SOCIETY OF AMERICAN FORESTERS

ON the occasion of the celebration of the thirtieth anniversary of the founding of the Society of American Foresters, which is to be held on the 29th to 31st December 1930 in Washington, D.C., that Society extends a cordial invitation to any of our members who can attend.

Further, the President of the Society, Mr. Paul G. Redlington, and Professor Ralph S. Hosmer, the Chairman of the Committee on International Relations, wish it to be known that it is the desire of members of their Society to be of such service as they may be to any European foresters who visit the United States. They state that they will be happy cordially to welcome such visitors, and thus in some measure reciprocate some of the many courtesies that have been shown to foresters from America when in Great Britain.

Foresters who propose to visit the United States are invited to communicate in advance with the Executive Secretary of the Society, Mr. W. R. Hine, 810 Hill Building, 839 17th St., N.W. Washington, D.C., who will be glad to put them in touch with those who can be of most assistance. If such visitors will state what they most wish to see, and persons they wish to meet, then suggested itineraries will be sent and arrangements made.

Those who have visited foreign countries know how valuable such help is, and we wish to very cordially thank the Society of American Foresters for this so kind offer, which we are sure will be accepted and appreciated by any members who visit the United States.

It will also be the desire of all our own members to render all possible help to American foresters who visit this country, and we join with the Society of American Foresters in hoping that foresters in each country will be able in increasing numbers to visit the other country and get to know their fellow foresters and the conditions and problems with which they have to deal.

REVIEWS

Review of Forestry Literature published in Finland in 1929.

By U. Metsänheimo.

THE great development in forestry in Finland has been fully reflected in the increase in publications. An increase in literature adapted for practical use is particularly noticeable, while the development and expansion of research has also very much augmented the number of publications.

On the fiftieth birthday of Professor A. K. Cajander, the Society of Forestry in Suomi dedicated to him, the founder and honorary member of the Society, a special publication in his honour: 'Commentationes in honorem professoris A. K. Cajander quinquagenarii editae', a notable tribute. It is a large publication (1,057 pages of letterpress and 147 illustrations), containing long and short researches and essays in various spheres of forestry science. Of the forty-two authors half are foreigners, including the following Anglo-Saxon names: Mark L. Anderson, L. Cockayne, John W. Harshberger, W. E. Hiley, R. S. Troup.

The work, besides being an issue for a special occasion, has been published in the series Acta Forestalia Fennica, no. 34.

Among the literature dealing with silviculture published in the course of the year, E. Laitakari's work, 'The Root System of Pine (*Pinus silvestris*)' (in Finnish, with an extensive English summary), may be mentioned. The work had already been published (in 1927) as an academic treatise, but has now appeared in the series Acta Forestalia Fennica. The same author has written a study, 'The Importance of Root Investigations for Practical Silviculture' (in German; Acta Forestalia Fennica, no. 33) and 'The Ability of Trees to withstand Storms' (in German; Acta Forestalia Fennica, no. 34). As a thesis for the degree of doctor, V. Pöntynen published 'An Investigation into the Occurrence of Spruce (*Picea excelsa*) in the Undergrowth on the State Lands of the Carelian Border' (in Finnish, with an extensive German summary).

In addition to investigations on forest types, Yrjö Ilvessalo has published 'Notes on Some Forest (Site) Types in North America' (in English); K. Linkola, 'Study of Forest Types in Esthonia' (in German), which appeared in Cajander's anniversary publication (Acta Forestalia Fennica, no. 34); and Viljo Kujala published 'Study on Forest Types of Petsamo and the Borders of Inari Lapland' (in German) [Comm. Inst. quaest. forest. Finl. 13].

P. S. Tikka published a dendrological study on 'The Growth and Development of Exotic Species of Trees in a Private Garden in Kulosaari' (Acta Forestalia Fennica, no. 35; Finnish, with summary in German).

The series Commentationes Forestales contains investigations and articles dealing with forestry in other countries than Suomi and kindred subjects. A preliminary communication, 'A New Method of Forest Planting', by K. Melders (Latirja), appeared in volume no. 3 (in German).

A work by V. Lihtonen, 'The Improvement of the Condition of Badly Treated and Poorly Productive Forests' (in Finnish), has appeared as a publication of the Central Forestry Association, Tapio, and a booklet, 'The Rational Care and Utilization of the Forest' (in Swedish), was written by Erik Borenius and published by the Insurance Company, Sampo.

The most notable publication on Forest Economics is 'The Forests of the Main Watershed Areas of Suomi (Finland), Results of the General Survey of the Forests of the Country carried out during 1921–1924' (prepared by Y. Ilvessalo). The chief part of the work is provided with plates and tables, to which a short summary in English is appended. The work was published in no. 13 of the Forest Research Institute. In the same volume, 'Helsinki as a Consumer of Wood Fuel' (Finnish, with summary in German), by N. A. Hildén, was also published.

Eino Saari: 'Return of Private Farm Forests in South Suomi', appeared in Acta Forestalia Fennica, no. 34 (Finnish).

The same author has also published a study on 'Stumpage Price of Spruce Pulpwood in Different Parts of Suomi, 1923–1926' (Finnish) (the *Finnish Paper and Timber Journal*, no. 20, 1929).

The last-mentioned studies have English summaries, and tables and plates with English text.

As an academic thesis appeared 'The Economic Aim of the Management of Forests', by E. A. Martin Hagfors (in German).

In the Silva Fennica series two volumes were published, of which no. 11 contains 'A Scheme for Introducing Permanent Statistics of Wood Consumption in Suomi' (Finnish, written by Eino Saari) and no. 12, 'Prospects for Promoting Forestry in Suomi' (Finnish); to each of them a short English summary is added.

In the sphere of Forest Technology several publications were issued during the past year, such as:

K. G. Ingman: 'The Handbook of Lumber-men' (Finnish).

I. Lassila: 'On the Influence of Forest Type on Weight of Wood' (Acta Forestalia Fennica, no. 36; Finnish, with English summary).

Matti Jalava: 'The Measuring of Round Piled Wood' (Finnish).

Paavo Aro: 'An Investigation into the Apportionment of the Quantity of Wood Cut between the Wood used and the Waste left in the Forest' (Finnish) and 'An Investigation into the Quantity of Bark and the Wastage of Barking in Spruce, Pulpwood, and Pit-props' (Finnish).

The three last-mentioned works were published in the Forest Research Institute's publications, nos. 13 and 14, and contain English summaries.

Artturi Käpy published a work, 'Saw-mill Technology IV. Sale and Shipping of Sawn Goods' (Finnish).

At the expense of the Central Forestry Association, Tapio, 'True Volume Tables' (Finnish) were published (Pöntynen, Aro, Saari), which contain factors for converting the cubic volume of timber quantities expressed in different measures into true (solid) measures.

The literature on the question of swamp-draining was enriched by several works. Of these the Forest Research Institute's publications, nos. 14 and 15, contain O. J. Lukkala's 'Investigation into the Degree of Acidity of Peat-bogs and the Influence of Ditching on it' (in German) and 'An Investigation into the Suitability of Peat-bogs for Draining' (Finnish, with summary in German).

From the point of view of swamp-draining, E. G. Svinhufvud's thesis, 'An Investigation into the Influence of Burning on Peat-bog Cultivations', is also interesting (Finnish).

'The Determination of the Suitability of Peat-bogs for Draining' and 'The Ditching (draining) of Marshy Forestland', published by the Central Forestry Association, Tapio, and written by O. J. Lukkala, are practical peat-bog books (Finnish).

'An Investigation into the Relationship between Timber Floating and Pisciculture' (Finnish), written by T. H. Järvi, was published by the Finnish Floating Association.

During the past year the following booklets were published by the Central Forestry Association, Tapio: 'The Preliminary Work for Working Plans' (Finnish, by V. Lihtonen) and 'Private Forest Law with Statutes and Explanations, Forest Improvement Law with Statutes' (Finnish).

For a committee report dealing with forests as credit security and its organization, Y. Ilvessalo drew up an appendix: 'The Valuation of Forests as Credit Security' (Finnish).

The following are large works in which forestry is dealt with: the Finnish Atlas with text-books (Finnish, English, and Swedish), published by the Geographical Society, and the Agricultural Encyclopaedia (Finnish), the forestry articles in the last-mentioned having been entrusted to A. Benj. Helander.

Collected lectures are contained in the publications, 'Finnish Forest Days V' and 'Economic Questions of the Day' (Finnish) (Publications of the Central Union of the Finnish Wood-working Industry).

The Annual Report II (Finnish and Swedish) of the Society of Private Foresters was full of information, comprising among other things data concerning the forestry of the Finnish Wood-working Industry.

The Warkaus Works having been for twenty years in the possession of the firm of A. Ahlström, O.Y., a special publication: 'Warkaus Works, 1909–1929' (Finnish), by Emil Vesterinen, was published to commemorate the event.

N. A. Hildén wrote an introductory booklet, 'The Forests and Forestry of Suomi', which was also published in English and Spanish.

During the past year 'Forestry Statistics for the year 1927' were issued (Finnish and Swedish, with summary in French).

In addition several publications have appeared under the aegis of the Economic Council (Chairman, A. K. Cajander), appointed by the Government in 1928, in which forestry and kindred questions are dealt with.

In spite of the present serious economic difficulties, the continually increasing forestry activities ensure that publications on forestry will continue to multiply.

Recent Research on Plot Technique and Statistical Analysis.

A Note by H. M. Steven.

A POST-WAR forestry feature of some interest is the increasing realization of the need for silvicultural research, and the specialist silvicultural research officer is no longer a rarity. The attention of not only such specialists but of all who have to plan silvicultural experiments should be drawn to the publication entitled *The Arrangement of Field Experiments and the Statistical Reduction of the Results*, by Fisher and Wishart.[1] The Imperial Bureau of Soil Science, under whose auspices this communication appears, is to be heartily congratulated on having secured its preparation.

The object of this publication can best be conveyed by quoting from the introduction: 'This memorandum aims at explaining the principles underlying the field experimental technique recently elaborated at Rothamsted, and gives, with appropriate illustrations from actual experiments, the full arithmetical working involved in the statistical reduction of the data. The memorandum stresses two points of importance:

[1] *The Arrangement of Field Experiments and the Statistical Reduction of the Results*, by R. A. Fisher, Sc.D., F.R.S., and J. Wishart, D.Sc. Imperial Bureau of Soil Science, Technical Communication no. 10, Rothamsted Experimental Station, Harpenden, Herts., England.

(1) the desirability of uniformity of procedure, and (2) the necessity for a field technique which shall minimize experimental errors and at the same time provide for an estimate of these errors by valid statistical methods. Small experiments may sometimes have their value assessed by cursory examination of the results, provided the differences are sufficiently striking to be obvious. Very few experiments, however, are of this nature. In the majority of experiments the averages appear to indicate a response to some fertilizer, or a superiority of one particular variety over another, but an element of doubt remains as to how far the differences in those averages may be due to chance. *No one would now dream of testing the response to a treatment by comparing two plots, one treated and the other untreated.* The idea of replication has become firmly established. Even the crudest of examinations takes into account the variation of the replicates before assessing the value of the difference between the means of two sets, and if the experiment consisted of nothing more than a number of sets, distributed at random over the field without any attempt being made to allow for soil differences, then some sort of criterion could be arrived at on the basis of experience by the individual worker, whereby he could assert that differences of a certain magnitude were probably real. Without statistical analysis, however, two experimenters would not necessarily draw the same conclusions from the same experiment. In doubtful cases the significance of observed differences should be expressed precisely, i.e. in the shape of certain odds for or against the reality of the phenomenon detected.'

The italics are ours. The thesis thus presented is generally accepted by agricultural investigators, but we fear that there are many silvicultural investigators who are still prepared to test the response to a treatment by comparing two plots, one treated and one untreated, and many research publications still appear detailing such investigations. The need for special methods of plot replication and analysis in forestry may be questioned, but it would be difficult to substantiate such doubts. The reviewer first applied Fisher's method of the Latin Square chessboard to forest nursery experiments in 1925, and all subsequent experiments reported in Forestry Commission Bulletin, no. 11, 1928, were carried out on this method of replication or Randomized Blocks, and analysed on the lines laid down in the communication under review. The data presented showed conclusively that these methods were not only applicable but necessary in forest nursery experimental work. They have been applied successfully to problems of artificial formation, and the data obtained indicated that reliable results could only be so obtained. We began an investigation to provide data regarding their application to thinning investigation, but it has not been possible to complete this. The application of the method to such problems by the Research Branch of the South African Forest Department may, in due course, however, provide interesting data on this latter point.

On theoretical grounds there is no doubt that suitable methods of plot replication are as necessary in silvicultural as in agricultural investigations, and the experience obtained as indicated above substantiates it. In nursery and establishment problems, where the response of a considerable number of different treatments often have to be studied at one time, the Randomized Block arrangement is best, while in thinning and natural regeneration problems, where the treatments to be studied are generally fewer, the Latin Square arrangement, where there are as many replicates as treatments, is to be preferred, because a more critical analysis is possible.

The careful study and application of the methods detailed in this communication will result in an appreciable advance in methods of silvicultural research, and it is cordially recommended to former students who are already applying these methods, and to all others who have to plan and carry out silvicultural experiments.

The second communication refers to a matter of detail in the application of the above methods. In a set of replicated plots the value for one plot may be missing owing to an accident. This upsets the analysis and a method for estimating the value for the missing plot, utilizing all the known plot values, is now available.[1]

The arithmetic to determine the estimate (k) of the missing value is simple and can be obtained for Randomized Blocks from $k\ (n-1)\ (s-1) = (n+s-1)\ S - s\ S_t - n\ S_b$, where s = number of treatments

n = number of replicates

S = sum of all the known $(ns-1)$ plot yields

S_t = sum of treatment totals not including the treatment of which one plot is missing.

S_b = sum of block totals not including the block with the missing plot.

The value so obtained is inserted in the table and the variance calculated as usual but with one degree of freedom less than usual.

Similarly for the Latin Square

$$k = \frac{1}{n-1} S_1 \frac{2}{(n-1)(n-2)} S_2$$

where S_1 represents the sum of the yields of the 3 $(n-1)$ plots which agree with the missing plot in row, column, and treatment, and S_2 is the sum of the plots which do not agree.

Home Grown Timbers. Their Anatomical Structure and its Relation to Physical Properties. Elm. By S. H. Clarke, Dept. of Scientific and Industrial Research, Forest Products Research Bulletin, no. 7, 1930, 27 pp., 12 plates. H.M. Stationary Office, Adastral House, London, W.C. 2. Price 3*s.* 6*d.* net.

Review by L. Chalk.

THIS bulletin is the first of a series which aims at giving a detailed account of the anatomy of the more important home-grown timbers and its relation to their physical properties. Only a very brief incursion into the subject is needed to convince one of the importance of variation within the species, particularly in relation to the selection of comparable samples. This point is well illustrated in the frontispiece, which contrasts the cross-sections of two sections, one from the inner and one from the outer part of a tree. It is also very important in many cases to be able to judge whether or not a sample is of normal wood, particularly in cases of unusual weakness. It is obviously impossible to do this without a thorough knowledge of the range of structure common to the species, and it is one of the objects of the bulletin under review to supply this knowledge. Consequently a large part of the bulletin is devoted to a study of the range of anatomical variation, the species selected for investigation being the common elm, *Ulmus campestris* L., the Wych elm, *Ulmus montana* Stokes, and the Dutch elm, *Ulmus major* Smith. This work, involving a very large number of measurements, has been carried out with thoroughness and originality and, quite apart from the results obtained, should prove very useful both as a guide to the treatment of other timbers and as an account of the technique evolved.

In the latter part of the bulletin an attempt is made to correlate anatomical variation with specific gravity and maximum crushing strength in compression parallel to the grain. This is a very complicated problem owing to the number of factors involved and the impossibility of isolating them. The choice of elm, with its complex anatomy

[1] 'A Method of Estimating the Yield of a missing Plot in Field Experimental Work', by F. E. Allan, M.A., and J. Wishart, D.Sc. *Journal Agricultural Science*, xx, pt. iii, 1930, pp. 400–6.

and irregular growth, as the first timber to be treated in this way argues no lack of courage on the part of the author. But the choice is to be welcomed on other grounds, as our knowledge of the timber of the different elms is extremely scanty. No very close correlations between any two factors were obtained in this part of the work, but there is much of value as indicating the relative value of different features, and some of the negative results are interesting.

Anatomical variation is treated largely with reference to position in the tree, and the most striking feature appears to be a progressive coarsening of the texture of the wood (i.e. an increase in the size of the cells) during youth, followed by an 'adult' stage in which the dimensions remain approximately constant. The latter stage is, however, characterized by irregular variations in the proportions of the different tissues. The author puts forward the interesting hypothesis that during early life growth is not usually limited by external conditions and that the progressive change in cell-dimensions is due to the action of hereditary 'internal' factors; in later life the needs of the tree are not so easily satisfied, with the result that external conditions tend to become the limiting factor, manifesting themselves in changes in the proportions of the various tissues.

The importance of this idea is twofold: firstly, since the relative proportions of the various tissues are closely bound up with the properties of the timber, the latter may presumably be influenced by silvicultural treatment; secondly, the size of the cells would appear to be of much greater significance for diagnostic purposes than the proportions of the tissues, as size is less liable to fluctuate with changes in the conditions of growth.

Neither ring-width nor percentage of summer wood were found to bear any constant relation to specific gravity, but correlation coefficients of $+0{\cdot}67$ to $0{\cdot}89$ were obtained between fibre volume and specific gravity. The correlation coefficient between fibre volume and strength, however, was only $+0{\cdot}27 \pm 0{\cdot}10$. In seeking for the reason for this unexpectedly low value, the author was led to some interesting observations on the tertiary thickening of the fibre-walls. This tertiary layer is often abundant in elm, and appears to be formed at the expense of the secondary wall. It adds to the specific gravity of the wood without appreciably increasing its strength. Indeed, where it is abundant, the secondary wall is correspondingly reduced, and a thick tertiary layer is generally associated with weakness in the timber. By using the width of the primary and secondary walls only, correlation coefficients of $+0{\cdot}44 \pm 0{\cdot}8$ and $+0{\cdot}57 \pm 0{\cdot}09$ were obtained with strength in the Dutch and Wych elms. Several other interesting points are made, such as the differences between the species, but space forbids mention of them all. The statistical treatment of the measurements adds conviction to the author's statements, and the principal relationships are also illustrated by graphs. The excellent photomicrographs which are included at the end will be found particularly instructive to those who are not familiar with the wide range of structure to be met with in these timbers.

The author is to be congratulated on his treatment of a very difficult and laborious piece of research.

Untersuchungen über den Einfluss der Fällzeit auf die Eigenschaften des Fichten- und Tannenholzes. I. Der Einfluss der Fällzeit auf einige physikalische und gewerbliche Eigenschaften des Holzes. By HERMAN KNUCHEL, Beiheft zu den Zeitschriften des Schweizerischen Forstvereins. Bern, Buchdruckerei Büchler & Co., 1930.

Review by B. J. RENDLE

FOR centuries it has been the general practice in Europe to fell timber when the sap is 'down'. The custom, like so many traditional operations of a similar kind, probably owes something both to experience and expediency; for, although there is a widespread prejudice among wood-users in favour of winter-felled timber, there are several independent but potent considerations which combine to make it more convenient for the forester to carry out felling operations in the winter. Previous research has failed to discover any inherent difference between wood from trees felled at different seasons, but has shown that the quality may be materially affected by the conditions to which the timber is exposed after felling. Chief among these is the greater liability of spring- and summer-felled timber to be attacked by wood-destroying insects and fungi. This report deals with the first part of an investigation into the influence of the felling season on the technical properties of Norway spruce and Silver fir. Between September 1926 and August 1927 selected trees in a 120-year-old stand of spruce, silver fir, and beech were felled at monthly intervals. In order to eliminate the variable effect of the sun, the timber was felled in the early morning and piled under cover. Mechanical tests were carried out on specimens in the green and air-dry conditions and various other physical properties were investigated.

To summarize the results. It was found that the time of felling exercised no substantial influence on the specific gravity, moisture content, shrinkage, resin content, or working qualities. Important differences were observed in the rate of drying; samples from trees felled between October and January dried extraordinarily slowly and evenly, taking 6–8 months to reach the air-dry condition, while samples taken between May and July attained the same condition in 1–2 months. It is especially noteworthy that the slow drying rate of the winter-felled samples was maintained through the summer months, so that these samples were overtaken by others which were felled later in the same year. The results of the tests on mechanical strength are not included in the report but will be published elsewhere.

In a series of carefully controlled experiments of this kind it is inevitable that the attempt to eliminate all factors but the one under examination results in the experimental conditions being widely different from those which prevail in actual practice. Taking it for granted that the preference for winter-felled timber rests on a real difference in quality, the fact that, under the conditions of the experiment, the felling season had no important effect on the technical properties serves to concentrate attention on the conditions under which extraction and conversion are usually conducted. It is then seen that the real influence of the seasons is through the effect of the weather, in controlling the drying of the timber and the activity of insects and fungi. Having regard to these conditions, it is concluded that the most suitable season for felling is autumn and early winter (from September to the end of November). The earlier in the autumn the timber is felled, the more likely it is to dry down gradually to a reasonably low moisture content and the less likely to be attacked in the spring by fungi and insects.

It is generally admitted that in the past forestry has been too much concerned with volume production and too little with the improvement of quality. In recent years

signs have not been lacking of a change in attitude and it is also realized that wide economies can be effected by intensive utilization methods. A report such as this, which directs attention to the ways and means of minimizing the deterioration of timber after felling, comes at an opportune time.

The results of tests on the durability of samples under ordinary conditions and after artificial infection in the laboratory will form the subject of a second report to be published at a later date. Judging from an account of this work which was given to the Fifth International Botanical Congress at Cambridge, these results are likely to prove the most important of the whole investigation.

Studies of the Sirex Parasites. By R. N. Chrystal, Hon. M.A., D.Sc. (Edin.). *Oxford Forestry Memoirs*, no. 11, 1930.

Review by W. R. Thompson, The Imperial Bureau of Entomology.

THIS important paper deals with the biology and post-embryonic development of *Ibalia leucospoides*, the curious Cynipid parasite of the wood-wasps, *Sirex cyaneus* and *Sirex gigas*.

The wood-wasps or horn-tails are large wasp-like insects allied to the saw-flies, whose larvae bore into the wood of living trees, and also attack felled timber. In Europe and America they do not ordinarily appear to infect healthy trees and are considered by most authors to be indicators of unhealthy conditions rather than true primary pests. In New Zealand, however, they seem to be much more dangerous, causing severe damage to *Pinus radiata* and attacking both felled logs and living trees.

Owing to the anxiety caused by the work of the wood-wasps and their increase in numbers, the New Zealand Government approached the Imperial Bureau of Entomology some years ago with a request for the investigation of the European parasites of these insects in the hope of eventually introducing them into the Dominion. The investigations were carried out in co-operation by Dr. Chrystal, of the Imperial Forestry Institute, and Dr. J. G. Myers, of the Imperial Bureau of Entomology, with the assistance of Mr. H. S. Hanson. The inconvenient habits and slow development of the wood-wasps and their parasites and the very extensive manual labour necessary in order to obtain material for study, made this investigation and the task of obtaining material for shipment, unusually arduous. In spite of these difficulties, Messrs. Chrystal and Myers succeeded in working out in detail the life-history of the *Sirex* and its parasites. It may be of interest to note that, as a result of these studies, some 1,300 larvae of one of the parasites (*Rhyssa persuasoria*) have been collected and shipped successfully to New Zealand, where the adults have been liberated in the forests, and have already been observed attacking the larvae of the *Sirex* in their burrows.

Dr. Chrystal's paper on the biology of *Ibalia* shows what a rich fund of valuable scientific information is available to the economic entomologist trained on modern lines and able to appreciate and utilize the material obtained during the study of insect pests. In this case, an investigation originally undertaken for purely economic ends has been the occasion of a most interesting monograph on a parasite of a very unusual type, occupying a unique position in the group to which it belongs. The descriptions of the developmental stages, accompanied by an abundance of excellent figures, admirably reproduced, constitute a very important contribution to our knowledge of the parasitic Hymenoptera. It is to be hoped that Dr. Chrystal will continue his studies on the parasites of forest insects, particularly the wood-borers, since we have as yet little accurate information regarding these forms, though they are often of great practical importance.

The main criticism of the paper that may be offered is that it would have been somewhat the better for energetic compression and a more careful separation of statements of facts from theoretical discussions. The principal reason for describing the larvae of parasitic insects is not that they are strange and curious—on the contrary, their anatomy is for the most part somewhat uniform and monotonous—but that we want to be able to recognize them. In other words, descriptions of larval parasites are, or should be, simply systematic descriptions, and in framing them we should aim rather at the lucidity and precision of the trained taxonomist than at the diffuse and speculative style of the old-fashioned philosopher. We do not mean to suggest that speculation should be avoided. On the contrary, it should be encouraged, because only by speculating upon the significance of the data furnished by observation can we reduce them to an intelligible form. The hypotheses put forward by Dr. Chrystal add greatly to the interest and value of his paper; but the outlines of both hypotheses and facts would be more clearly apparent if these categories had been distinguished and dissociated.

Big Trees. By Walter Fry and John R. White. Humphrey Milford, Oxford University Press, London, 1930. Price 9*s.*

Review by the Editor.

THIS is an interesting, popular book on the giant Sequoias of the western slope of Sierra Nevada, California. One of the charms of the book is the excellence of the photographs of the Big Trees, *Sequoia gigantea*, and the Coast Redwoods, *Sequoia sempervirens*, although the former only is the subject of the book. The prose, although somewhat full-flavoured in places, is not crude American, and the sponsoring of the book on this side by the Oxford University Press is a guarantee in this respect.

The book gives a general account of the Big Trees from the cradle to the grave, framed in their primeval history. Their greatest popular appeal is the age and size which they attain. Our race particularly is always attracted by virile old age. It is stated that 'it is certain that they can live 5,000 or 6,000 years, probable that they may live 7,000 or 8,000 years, and not improbable that they will live over 10,000 years, almost forever, if protected in national parks'. In size these trees are equally impressive. General Sherman is 273 feet 9 inches high, has a maximum base diameter of 37 feet 3 inches, and is estimated to weigh 6,167 tons. Such trees are unique amongst living things, and this all comes from a seed not one-fourth of an inch long, and 'the kernal is not thicker than a medium-sized cambric needle'. There is no better example of the possibilities of accretion.

This is a book which is designed for all, and we cordially recommend it not only to foresters but to every one who is interested in Nature's handiwork. In passing we would congratulate the American nation on the steps it is taking to preserve these wonderful trees.

Tenth Annual Report of the Forestry Commissioners, Year ending 29th September 1929. H.M. Stationery Office. Price 1*s.* 3*d.* net.

Review by Thomas Thomson.

THIS report is specially interesting as during the year the course of the ten-year period covered by the Financial Section of the Forestry Act, 1919, expired. Advantage has been taken of this milestone to review the progress of the work during that period and to formulate the programme for the next decade.

The total sum paid into the Forestry Fund from the Exchequer during the ten financial years ended 31st March 1929 was £3,500,000, of which £430,000 was voted for the relief of unemployment. Receipts from operations amounted to £783,755,

and in accordance with the Forestry Act, 1919, were paid into the Forestry Fund. Although in the end the full statutory amount was credited to the Forestry Fund during the ten-year period, there were times of considerable uncertainty as to the annual provision of funds—notably after the presentation of the Geddes Commission Report—when the Commissioners were forced to make many reductions of staff and curtail essential activities which seriously interfered with the development of the work.

During the ten and a half financial years covered by the Report, the total expenditure amounted to £4,502,018, and an analysis is given showing the percentage of the expenditure under various heads. The largest proportion is represented by the cost of forestry operations, 69·3 per cent. This, together with forest workers' holdings, 7·2 per cent. represents the main effective functions of the Commissioners. Salaries, wages, &c. (excluding foresters and foremen), and central administration account of 13·8 per cent. of the expenditure on the average for the period. An interesting diagram is given showing the changes in the proportion of the expenditure under these heads during the course of the ten-year period. The percentage of expenditure under the heads representing superior supervision and headquarters charges has fallen from 30·3 per cent. in the first year to 10·9 per cent. in 1929, whilst that under the heads of forestry operations and forest-workers' holdings has risen in the same period from about 63 per cent. to 84 per cent.

The following table shows in parallel columns the work done during the decade and the proposals of the Acland Committee:

Work.	*Acland Programme.*	*Actual to 30th September 1929.*
	acres.	acres.
Acquisition of plantable land.		
For planting conifers .	382,000	310,230
Devastated hardwood areas	20,000	
	402,000	
State planting.		130,768
Conifers . . .	150,000	7,511
Hardwoods . . .	Unspecified	
		138,279
State-aided planting . .	110,000	76,736
Forest Workers' Holdings	Nil	618 completed
		245 in progress

The acquisition of land has fallen behind mainly for reasons of uncertainty in finance, but also owing to the difficulty of securing afforestable land only in distinction to mixed subjects. The average price paid for plantable land was £3 5*s*. 9*d*. per acre. Hitherto the Commissioners have not found it necessary to put into operation the compulsory powers they possess and hope to continue to supply their requirements, even with the increased annual planting programme of the next decade.

On 30th September 1929 the Commissioners had under their charge 602,000 acres of land, of which 251,000 acres had been acquired by purchase, 231,000 acres by long lease or feu, and the balance, 120,000 acres, had been transferred to them by the Commissioners of Crown Lands under the Transfer of Woods Act, 1923. The total area of forest was 202,733 acres and 164,168 acres of plantable land were awaiting afforestation. The total area of forest and potential forest was, therefore, 366,912 acres.

An interesting description of the main types of land acquired by the Commissioners and their distribution over the country gives an idea of the variety of problems which have to be faced. It is hoped by experiment to find means of dealing with the difficult types like deep peat and high heather moor.

The second part of the report deals with the proposals for the new decennium, 1929–39. Briefly, the Treasury have agreed to ask Parliament to vote as grants-in-aid over the ten years, 1928–38, such sums not exceeding in the aggregate £9,000,000 as might be necessary to carry out an afforestation programme of 330,000 acres for the decade and to create 3,000 forest workers' holdings. In addition receipts from forestry operations (estimated at £2,160,000) will be available. The total sum will thus be £11,160,000 which is £115,000 less than the estimated expenditure for the programme (which includes 23,000 acres of replacements in addition to 330,000 acres of afforestation) together with the other expenditure of the Commission in advances for afforestation purposes, education, research, special services, and forest workers' holdings. The estimated cost of the last-named is £1,870,000 for 3,000 holdings.

The report again points out that the private woodlands have not shown that recovery and improvement which it was hoped for when the Acland Report was drawn up in 1917–18. In reviewing the whole situation with regard to private forestry the Commissioners have come to the conclusion that, while they do not suggest any immediate changes, it may become necessary in due course to ask Parliament for additional powers.

The third part of the report deals with the operations of the Forest Year, 1928–9. The net acquisition during the year amounted to 34,317 of plantable land and the area planted with conifers to 20,680 acres, compared with 30,000 acres under the Acland programme. The usual analysis of expenditure under various heads is given. The average rent or feu duty for land acquired for forestry operations during the year by lease or feu was approximately 2*s.* per acre and the average price for land purchased, approximately £2 per acre, or if the whole be charged against plantable land only, 2*s.* 8*d.* and £3 3*s.* respectively. Land and buildings for forest workers' holding are excluded.

The outlay per acre on labour and material on the area planted between 1919 and 1929 was as follows:

	£ *s.* *d.*
England and Wales	8 10 0
Scotland	9 15 0
Great Britain	8 18 0

A feature of the year was the amount of damage suffered by fires in the woods. The severe frosts of the winter rendered the old vegetation very dry and the lack of rain later retarded the growth of young grass. During the year 409 fires occurred, affecting 4,574 acres. The damage done was estimated at £45,961, the amount for which claim has been made being £10,494. Thirty-six per cent. of the fires are attributed to the general public and 35 per cent. to railway engines.

During the year further progress was made with the formation of forest workers' holdings, as shown below:

Progress in Formation of holdings.

	At 30th September 1928.	*At 30th September 1929.*
Completed . . .	490	618
In course of formation .	282	245
	772	863

The average cost of these holdings is as follows:

Value of land £75; cost of buildings, drainage, water-supply, &c., £483. Total cost of establishment £558.

The average area of land attached to a holding is 10 acres, and the average rent paid is £14 per annum.

The amounts and values of imports of timber, wood manufactures, and pulp of wood are given in an appendix to the report. Graphs are given showing the figures for the period 1920 to 1929.

The report is of more than usual interest because of the survey of past operations and discussion of future plans which are included in it.

Report of the Forest Products Research Board, 31st December 1929. H.M. Stationery Office, Adastral House, Kingsway, London, W.C. 2. Price 4*s*.

Review by the EDITOR.

THE volume of research work which this report records is a measure of the progress which has been made since the staff settled down in the new laboratory at Princes Risborough. The period of equipment and staffing is being followed by one of definite achievement. During the year under review the scope of work was widened by the inclusion for the first time of services on behalf of the Empire overseas.

This report is not of the usual type; it is rather a series of research papers dealing with the different aspects of the board's activities. It is noteworthy that the more scientific aspects occupy a considerable part of the report. Although the balance between the less immediately and more immediately practical activities is, no doubt, weighed down in favour of the former in that it more readily lends itself to presentation, we welcome this recognition of the long view. Although wood structure, wood chemistry, and biological studies of insects and fungi are somewhat removed from the sale and use of timber, definite improvements in these respects can only be expected when knowledge of wood and its reaction to environment in a wide sense is substantially increased.

A very large range of subjects is dealt with, and only a few of these can be touched on here.

One of the characteristics of living matter is variation, and timber, one of nature's most important products, is a notable example. An investigation is in progress to determine the range in anatomical structure for given species, and to study the relationship between such variation and properties. The work for elm has been published and is reviewed in this number; a similar investigation for oak is in progress.

A section of the report is devoted to kiln seasoning. In this connexion tests have been in progress for a number of years to determine the optimum moisture content for furniture woods under different environments. The following are summarized figures:

	per cent.
Oak	13
Mahogany	12·25
Scots pine	11·5

A report on the tests of home-grown pitwood is about to be published. These show that Scots pine and Corsican pine are good pitwood timbers provided they are not seasoned below 25 per cent. moisture content, while Douglas fir is satisfactory if the average growth is not faster than 6 rings to the inch radius. In connexion with a preliminary investigation of mining collars, two lots of imported Maritime pine were tested, one of which had been bled for turpentine and one not so bled. It is interesting to note that the bled trees were found to be distinctly stronger.

A substantial amount of work on the wood-destroying fungi is recorded. In connexion with the standard tests of wood preservatives, a technique has been evolved of growing *Fomes annosus* and *Coniophora cerebella* on wood blocks treated with different preservatives, and determining the consequential loss in dry weight. Progress has been made in building up a collection of wood-destroying fungi, and in the study of the life-history and physiology of important species.

In the entomological section, the work on *Lyctus* has been continued; and progress has also been made in the study of the Furniture Beetles, *Anobium punctatum* and *Xestobium rufo-villosum*. In this connexion it should be noted that a special house is being erected to facilitate the study of the Death Watch Beetle and Dry Rot. Sections of the house will be infected, and methods of prevention and control studied.

The section of wood chemistry has been concerned in a number of investigations. For example, it has been found that there is a close similarity in the effect on wood between the incipient stages of 'brown rots' and mild acid hydrolysis, and this may lead to better methods of prevention of decay.

The progress of the laboratory is also reflected in the increase of visitors, advisory work, and general inquiries.

This is a report to be read.

The Proceedings of the Third British Empire Forestry Conference, Australia and New Zealand, 1928.

Review by THOMAS THOMSON.

THE Conference held nineteen sessions over the period 22nd August to 22nd October 1928 in various towns in Australia and New Zealand, and this volume contains reports of the speeches made and the discussions which took place on the very numerous and varied subjects dealt with during these sessions and on public occasions. In a short review it is impossible to do more than select a few points for notice and to give general impressions. The Governments of the Home Country, the various Dominions, Colonies, and Protectorates prepared and presented reports on the forestry of their respective countries, and while these reports are, of course, not included in the published matter, the brief speeches made by the representatives in presenting their statements in the early sessions of the Conference give a remarkable picture of the great differences in forestry conditions in the Empire.

The previous Forestry Conference (Canada, 1923) had passed a number of resolutions, and substantial progress in carrying out those dealing with forest policy was reported. The establishment of the Imperial Forestry Institute and the Forest Products Research Laboratory are two of the important steps taken carrying out resolutions passed at the same Conference.

After receiving the various reports of the delegates, the Conference proceeded to discuss a number of questions. The method of procedure adopted in many cases was to have a general discussion and then appoint a Committee for detailed examination of the problem. The Committee presented its report at a later session, and the matter was discussed again by the full Conference on the motion to adopt the report in question.

Committees were appointed, among others, to consider an Imperial Forestry Bureau, Australian forestry, forestry education, forest products research and Empire trade, exotics, trade names of empire timbers, &c., and discussions took place on other important subjects, such as forest policy, pulp and paper, timber supply and

consumption, silviculture and management, methods and lines of research, minor forest products, and climate and erosion.

Of the major subjects discussed mention may be made of forest policy, which, as Lord Clinton remarked in opening the debate, 'really covers the whole work of these conferences'. His lordship summarized the points he placed before the delegates as follows: (1) a forest policy can be laid down only by the Government itself, and should only be laid down after the fullest possible consideration of all the factors governing the case; (2) when once laid down, it should be regarded as the permanent policy, not subject to alteration, except for clearly defined purposes; and (3) there must always be the most complete and highly-trained staff that the Government can obtain. It is satisfactory to note that progress along these lines has been made in many parts of the Empire, but there is still much to be done before the successive British Empire Forestry Conferences need no longer to reiterate these fundamental truths.

The question of the training of recruits for the forestry services of the Empire was the subject of considerable discussion, and the report of the Committee set up to consider it dealt with it in three parts. The first part concerned training in general, and was in favour of concentrating this at a few fully-equipped schools. The second part dealt with the Imperial Forestry Institute, whose five-year initial period has come to an end and whose future was a matter of immediate concern. The third part dealt with forestry education in Australia. The report has been published and embodies in the main the trend of ideas expressed in the discussions. One is glad to note, however, a certain doubt in the minds of some of the delegates as to the advisability of making the training too exclusively technical, and also the recognition of the fact that no recruit fresh from a school of forestry, however well equipped and efficient it may be, can be expected to take full responsibility in his new sphere of work without a period of practical experience of the conditions he is expected to deal with.

The Committee on Trade Names of Empire Timbers compiled an 'Initial List of Standard Trade Names' with the corresponding botanical names, which is published as an Appendix to the Proceedings. It contains about 200 names of species which are already on the market in London and have been completely identified botanically. A supplementary list is also given of eleven timbers said to be already on the London market, but whose botanical identity is still uncertain.

Proceedings of the International Congress of Forestry Experimental Stations. Stockholm, 1929. Price 10 Swedish kronen.

THOSE concerned are to be heartily congratulated in securing the speedy publication of this volume of over 800 pages with contributors from all over the world.

The work of the Conference was organized into the following sections: silviculture, forest ecology, forest soil science, and entomology, and the papers printed were those delivered in these sections, and a general introductory section. Thus, while the field covered is by no means the whole of forestry, a great mass of material has been presented within the delimited fields, and the interpretation of these has been broad. Hence all who are interested in silviculture and the more biological aspects of forestry will find much of interest in this volume. In particular all European foresters will be interested in the opening paper, L. von Post's 'Die postarktische Geschichte der europäischen Wälder nach den vorliegenden Pollen diagrammen'.